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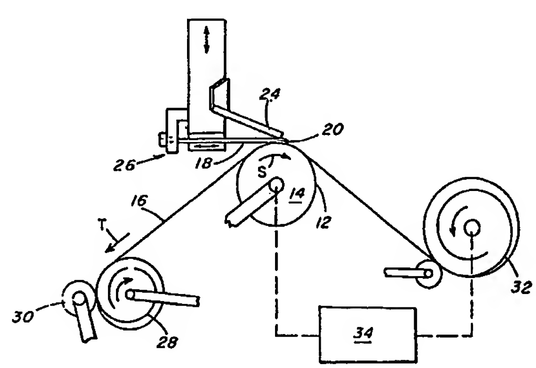
(54) Method and apparatus for longitudinally compressing web material.

(57) Longitudinal compressive treatment of web materials by features, that perform in concert. For driving a web longitudinally a stationary low friction member (20) pressed down upon a driven roll (12) provides multiple lines of pressure-concentration against the driven roll. These lines can provide a positive web drive over varying conditions, can isolate the final point of drive from supply tension, and can establish a relatively tensionless state in the web before final drive and longitudinal compressive treatment. When webs undergo longitudinal compression while confined under a continuation of the stationary low friction surface, minute steps in the stationary surface define a succession of slightly enlarging treatment cavities that stabilize the treatment under differing conditions. For retarding the web a flat, fluid-expansible envelope, overlying a stationary retarding surface, acts through a mediating member to regulate downward pressure between retarding surface and web. A spring sheet member having a decoupling hinge notch formed in its upper surface between feeding and retarding regions can decouple downward pressures in these regions, while providing smooth transition geometry between the regions. Mechanical work energy provided by the longitudinal compressive treatment



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under regulated treatment conditions provides heat that enables drying of treated paper and, in the case of treated thermoplastic webs, can cause permanent setting of the longitudinal treatment effects as they are produced in the web. In the case of a web that comprises thermoplastic fibers, permanent setting of a compressively bloomed state of the fibers is achieved by prewarming the web below the softening temperature of its thermoplastic fibers, controlling the web drive speed to exceed a critical level, e.g. about 15 yards per minute, longitudinally compressing the web using a stationary retarding surface that applies a drag force to the web, the longitudinal compression step imparting heat to the fibers through conversion of work energy, and chilling the web following the longitudinal compressive treatment. Special patterns in the web, and regulated degrees of strechiness are provided by special periodic variations in the retarding surfaces across the running width of the web.

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Field of the Invention

This invention relates to the longitudinal compressional treatment of flexible web materials such as knitted and woven textile fabrics, papers, plastic films, and so-called "non-wovens" the latter being of natural or synthetic substance, formed into webs e.g. as by air laying or wet laying of fibers.

Background of the Invention

In the laboratory from which the present invention comes, we have devoted many years to development of the treatment of webs in which longitudinal compressional forces are applied in the plane of the flexible web material. From this work has come a number of inventions, including the compactor, U.S. Patents Nos. 2,765,513 and 2,765,514; the bladed microcreper, U.S. Patents Nos. 3,260,778 and 3,426,405; and the bladeless microcreper, U.S. Patents Nos. 3,810,280; 3,869,768 and 3,975,806. As implemented by these inventions, the untreated web is driven longitudinally by using a low friction surface to press the web against a rotating drive roll, and then within a short distance of the drive point, retarding forces are applied to the traveling web. The opposition between the driving and retarding forces, while the material remains confined in the lateral direction, produces desirable physical change in the web material, for instance, increase in its bulk, thickness and elasticity.

In the case of textile and textile-like materials, the web can be compacted longitudinally within its own plane, without folding of the web upon itself or formation of a crepe, but with crimping _in situ_ of the tiny individual fibers ("microcreping" of the fibers) that make up the threads or yarns of the fabric.

In the case of solid thin sheets such as paper or plastic film, the longitudinal compressive treatment can form barely perceptible undulations or crepes in the web as a whole ("microcreping" of the web), in which the overall appearance of the faces of the web is still one of smoothness, without superficial coarse crepe or folds being present. If, however, coarse crepe is desired, this can be achieved by suitable enlargement of the treatment cavity.

In many cases desirable qualitities produced by the longitudinal treatment remain in the web after some or even all of the compression in length of the web is removed by stretching.

In specific examples the treatment can increase the softness or drapability of a web, increase its covering effect and opacity, make the surface texture of the web more appealing, render the web shrinkproof, apply decorative effects to the web, or cause components of the web to be more intimately interengaged in a way that is useful.

Paper webs can be made stretchy and have their burst resistance improved.

In the case of webs of synthetic polymer the effects of the longitudinal compressive treatment have been rendered permanent by heating the web to the heat-set temperature range that has been used in industry for setting other treatments of webs or fibers.

The longitudinal compressive treatment of webs as has been known from our earlier work has been successful in certain commercial applications, but in a number of such cases considerable operator skill has been required in order to deal with changing production conditions. Often the treatment has been limited to slow speeds or to only a limited range of starting materials and end products.

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A large number of cases have remained, particularly in the field of thin webs, in which commercialization has not heretofore been possible because of difficulty in setting up the treatment or in accommodating changes during running.

For these reasons there has been a long-standing need for better apparatus and method for the longtudinal compressional treatment of flexible webs.

To explain the limitations of prior approaches, it should be understood that there exist a large number of changeable production conditions that can affect the opposed drive and retarding forces of the longitudinal compressive treatment and contribute to difficulties of initial set up and continued operation. For example any of the following can occur: change in the web-gripping character of the drive roll, for instance due to wear of the drive roll surface or presence of foreign substances or due to change in roll speed; variations in pressure of the web against the drive roll, for instance due to change in the untreated web thickness or in the forces that press the confining surface and web against the drive roll or due to wear or change in the geometry of the confining surfaces; variation in the supply tension applied to the untreated web as it enters the treatment; change in the stiffness or softness of the untreated web as may occur due to change in moisture content or temperature of the original untreated web; change in the depth of the retarding passage through which the web passes; change in other retarder qualities due e.g., to dimensional or speed change; and change in susceptibility of the web to its being retarded, e.g., due to change in the frictional qualities of the web to be treated; and so forth.

In practice, more than one of the variable conditions often changes at the same time, producing a more complicated behavior.

In the cases where webs undergo their longitudinal compression while confined under a low friction surface, as a variable changes, the point of treatment of the material (i.e., the "O" point in the case of bladeless microcreping, as shown in Fig. 1 of our U.S. Patent No. 3,810,280) tends to shift forward or backward in the treatment region, further affecting the quality of the treatment.

The job of the operator has been to take all conditions into account when establishing the initial running adjustments of the treatment and then, during operation, to observe changes in the conditions as they occur and take steps in attempt to counteract these changes by compensatory adjustments.

In view of such difficulties, it is an important object of the present invention to provide new techniques for longitudinal compressional treatment of webs which reduce or eliminate such need for adjustment and enable a uniform, high quality treated web product to be obtained over a wide range of web materials. Other objects of the invention are to achieve increase in production rates, greater energy efficiency, and novel specific treatment processes for web materials.

These objects apply in general to a wide variety of means for the longitudinal treatment.

Furthermore, it is a specific object of the invention to improve the "bladeless" type of microcreping treatment. In "bladeless" microcreping a stationary retarding surface extends beyond the confining surface to lie over the driven roll, forming therewith a retarding passage in which drag forces are applied to the face of the web. This retarding surface is rough or abrasive-like and is inextensible in the direction of the web travel.

Use of such treatment on textile fabrics has generally been thought by commercial producers to require a highly heated (and hence softened) web and to require speeds limited to 5 to 10 yards per minute. While under the compression forces of the treatment, the surfaces of such a heated web have a glazed-like appearance, and when the web is subsequently stretched and cooled the web surfaces have a sharply defined profile that gives a feeling of harshness to the hand. Subsequent scouring and other treatments have been required to make such webs acceptably soft for commercial use.

Sporadic results in the laboratory have suggested however that a very soft fabric, with bloomed fibers and desired level of increased bulk could be obtained directly by longitudinal compressive treatment, without need for subsequent scouring or the like, but no reliable means has been available to assure these results under commercial production conditions and with the permanence needed to withstand a standard series of wash tests. Also, defects known as "picks" such as produced by broken fibers, and other surface imperfections have appeared when webs had been treated in this way.

Summary of the Invention

According to one aspect of the invention, a web drive for the longitudinal compressive treatment of web materials comprises a special stationary low-friction surface for pressing the web against the driven roll, this surface having a series of adjacent, exposed edges extending in the direction of the length of the roll and having surface lands extending between these edges. By urging a series of the edges simultaneously in pressure-concentrating engagement against the web, the web is simultaneously driven forward by the roll at multiple adjacent lines, in a manner that ensures uniform final driving of the web into the compressional treatment

over varying conditions. Preferably the edges are provided in the under surface of a sheet-form spring member and pressure toward the roll is concentrated on the upper surface of the sheet-form member at a location downstream of these edges, this pressure being effective to bend the sheet-form member about the roll and press the edges into their pressure-concentrating engagement against the web. Preferably the edges comprise integral formations in a unitary spring sheet steel member, the edges are at steps that lie no more than about .005 inch below adjacent land surfaces, and the edges are straight with each other

Another aspect of the invention concerns the specific longitudinal compressive treatment in which a stationary, low friction surface is first used to press the web against the driven gripping surface in a drive region to drive the web forward in the longitudinal direction and secondly, downstream thereof, a stationary low friction surface is used to confine the forward-driven web over the driven surface in an enlarged confining region. Downstream of this confining region retarding forces are applied to cause compressed material to accumulate in the confining region so that the forward-driven untreated material longitudinally compresses against previously compressed material before it leaves the confining region. According to this aspect of the invention, the forward-driven web is exposed successively to a series of minor, discrete stepped enlargements of the space between the low-friction confining surface and the driven surface, these enlargements increasing progressively along the travel direction in minor amounts, thereby presenting to the traveling web a series of adjacent, dimensionally similar zones in which longitudinal compressive treatment can occur. With this arrangement, as different treatment

conditions occur, the treatment can reliably occur in the confining region, but in different ones of the series of adjacent similar zones that make up the confining region.

According to another aspect of the invention the web is exposed to at least two successive discrete stepped portions of the stationary surface in the drive region; the first step is employed to define a concentrated drive pressure point to press the web tightly against the driven surface to apply drive force and draw the web forward to overcome web supply tension. The portion of the web extending downstream from this first step is confined and continues movement with the drive surface in a relatively tensionless state, essentially without compaction or slippage of the web relative to the driven surface. The following second step is used to enlarge the height between the stationary surface and the driven surface to present to the web a sufficiently enlarged confining zone in which longitudinal compressive treatment can occur, the edge at this second step being used to define a second concentrated drive pressure point to press the web against the driven surface, to drive the tensionless web forward against the accumulated compressed material. Advantageously, in this case too, the forward-driven web, starting at the second step is exposed successively to a series of minor, discrete stepped enlargements of the space between the low-friction stationary and the driven surfaces, to present to the traveling web a series of adjacent, dimensionally similar zones in which longitudinal compressive treatment can occur while the web is still confined beneath the low friction surface.

Further important features useful according to the invention are: a stationary surface in the drive and confinement regions which presents to the web a series of essentially planar, smooth polished lands extending in the direction of the web travel and discrete, minor riser

portions at the steps, with the riser portions extending at substantial angles to the planar lands and forming dams that resist backward migration of the compressed column; steps formed integrally in a single sheet form member as an extension of the pressing surface, preferably being of blue spring steel; steps of the order of 0.003 inches height; portions of the stationary low friction surface between adjacent steps extending longitudinally in length between about 10 and 30 times the amount of the rise of each step, preferably being of the order of 0.050 inches long; for treatment of certain predetermined web materials, the height of each step being no more than about one third of the thickness of the material; the stationary surface presenting to the web at least three of the minute steps that bound longitudinal compressive treatment zones; and where a retarding surface follows the confining surface, providing a minor step at the point of transfer of the web from the confining passage to the retarding passage without substantial change in passage dimension, preferably this step being of the order of 0.003 inch, and preferably the retarding effect being provided by a stationary retarding sheet overlying the driven surface and defining therewith the retarding passage, the confining passage serving to direct the web into the retarding passage in a path substantially parallel to the retarding surface. In a construction for masking picks the final lip of the retarder is provided with flutes to impose a fine pattern of longitudinal lines in the finished web. In a construction for producing a plisse effect or for regulating the spring quality of a stretchable web the retarding surface is in the form of thick fingers, with bubble-forming chambers defined between the fingers.

According to another aspect of the invention additional benefits can be realized by isolating the decoupling from the confining passage the forces that are applied when regulating the retarding passage. In this way the special geometry of the confining passage can be kept relatively constant during changes in the downward pressure at the retarding passage. In preferred embodiments of this aspect of the invention, in which stationary overlying sheet form members define the confining and retarding passages, decoupling is achieved by a strategically located hinge or notch formed in the sheet member at a point immediately downstream of the confining passage. This hinge, while enabling continuity between the web-confining and retarding surfaces, enables bending of the downstream end of the sheet-form member to produce selected levels of retarding force, without detrimentally transferring this force to the preceding confining passage. This can avoid tendencies to choke the flow of the material, avoid application of unwanted drive force at the outlet end of the confining passage, and help reduce wear of the primary confining surface.

In another aspect, the invention features fluid expansible envelope above a stationary retarding surface, which acts through a mediating member to deflect the retarding surface downward under control of air pressure while a member above the envelope resists its upward expansion. Preferably this feature is employed in conjunction with the specially notched or hinged sheet-form member mentioned above.

According to the invention we have furthermore made discoveries that improve the treatment of woven, knitted and nonwoven textiles, in order to produce smooth, desirable finishes under commercially acceptable conditions. As mentioned above, prior art microcrepers (such as the bladeless microcreper described in our '280

patent) have been found with delicate fabrics to produce picks (small disruptions or breaks in individual fibers), and to unevenly move the fabric during the microcreping. We have determined that one cause of picks is that portions of the fabric, perhaps because of localized areas of increased thickness, become locally choked within the confining passage so that the driven roll, as it slips past the fabric, tears at the threads. Examination of fabrics that have been removed from prior art microcreping heads after the driven roll has been stopped have shown that the line at which compaction initially occurs does not extend straight across the fabric, but rather tends to follow a wavy pattern. In some instances the line appears as a series of end-to-end half moons. Our invention solves this problem by providing a confining surface with the series of the minute steps followed by a sheet-form stationary retarder surface in a bladeless microcreper construction. Here the minute steps are found to produce a desirable uniformly straight compaction line or lines across the full width of the woven, knitted or nonwoven fabric being treated, irrespective of localized variations in the web. The result can be a smooth, pick-free compressionaly treated fabric.

According to another aspect of the invention we have discovered, with suitable arrangement of treatment conditions, that the longitudinal compressive treatment can itself produce highly useful levels of heating in the web, through conversion of mechanical work energy to heat.

Thus in the case of heat settable webs, when we desire to achieve a permanent set that is ordinarily achieved by heating the web to its recognized heat set range, we only prewarm the fabric to a temperature substantially below this range, and we drive the fabric through the longitudinal compressive treatment at

sufficient speed that the work-energy imparted by the compressional treatment enables a final set condition to be obtained. By introducing the web in a relatively cool condition, the fabric retains a degree of toughness that enables a substantial quantity of work to be performed, resulting in effective levels of self-generated heat.

This aspect of the invention is of particular importance in respect of fabrics comprised of yarns or threads of thermoplastic polymers such as nylon and polyester. In the treatment of such materials the prewarmed condition of the fabric is maintained at a temperature of the order of 50° F below the recognized heat-set temperature range of the material, but ordinarily above 200° F, the speed through the treatment is maintained at about 15 yards per minute or faster and the web is chilled after passing through the compressive treatment. When the fabric emerges from this treatment it has a soft hand and does not exhibit harshness or heat strains that are associated with preheating to the heat-set range. Its bloomed and densified condition is nevertheless permanently set and stable, (in the manner normally achieved only by heating the web into the heat set range) as demonstrated by retention by the web of its dimensions after a standard series of wash tests. This process therefore enables the permanent treatment of a knitted fabric as the final step in its manufacture, with prewarm temperatures below 300° F, ordinarily above 200° F, and without the need of subsequent scouring, heat-setting, tentering or trimming.

In one preferred embodiment of this aspect of the invention the material comprises nylon tricot knit fabric of a thickness of about .010 inch, the temperature of the web approaching the compressive treatment step is maintained in the range fo 240° F to 300° F, and the speed through the longitudinal compressive treatment is

maintained in the range of 15 to 30 yards per minute; in another embodiment the material comprises polyester tricot knit fabric of a thickness of aboout .010 inch, the temperature of the web approaching the compressive treatment step is maintained in the range of 220° F to 280° F, and the speed through the longitudinal compressive treatment is also maintained in the range of 15 to 30 yards per minute.

Preferably, for the self-setting process just described, the retarding member is of the drag-producing type having a pressure-sensitive longitudinal retarding characteristic which varies non-linearly with pressure of the fabric against the retarding surface. The characteristic is such that a moderate pressure produces a strong longitudinal retarding effect while a light normal pressure produces only a light retarding effect. In the process, the retarding surface is pressed to produce its stronger retarding effect at the upstream portion of the retarding surface and over a length of about 50 times the untreated thickness of the fabric, the retarding surface is pressed with decreasing pressure, to provide the lighter, and finally no retarding effect at the outer end.

In one embodiment, the retarding element is a plasma coated metal surface. The rounded nature of the projections (tiny particles e.g. of tungsten carbide that are embedded by the plasma-coating process) provide the desired grip and release characteristics on very delicate fabrics that are susceptible to tearing or picking. With less delicate fabric correspondingly more aggressive retarding surfaces, as defined by sharp abrasive points found in fine emery cloth, are employed.

From the discovery of useful self-heating in the treatment of fabrics we have realized that the concept may have a more general application to longitudinal

compressive treatment processes where the material requires ultimate elevation to a given process-demand level of temperature. According to the invention such processes are characterized by the steps of maintaining the material approaching the compressional treatment step at a temperature substantially below the process-demand level temperature and at a state of toughness adequate to enable the compressive treatment of the material to convert work energy to heating of the material to the process-demand level temperature, passing the material through the compressive treatment step under conditions to continually produce heat rise in the material to the process-demand level temperature, and relying upon such temperature rise in the completion of the process.

In preferred embodiments of this process the material is a thermoplastic synthetic polymer, the process-demand lever of temperature is a temperature at which the material can permanently set under longitudinal compressive treatment conditions and the material has a heat set temperature of the order of 350° or higher, and includes the step of maintaining the prewarmed temperature of the material approaching the compressional treatment step at a temperature below about 300° F but above 200° F.

In other embodiments of this process the material during longitudinal compressive treatment contains a volatile softening liquid and the process-demand level temperature is defined as a temperature required to enable evaporation of a major part of the volatile liquid when the web is exposed to ambient conditions. In preferred embodiments the material comprises a paper web, the volatile liquid is substantially water, limited amounts of this water are applied so that the fibers of the web remain tough, and the process demand level temperature is determined by the drying requirement of the paper. To produce a treated kraft paper suitable

for use in wrappings and paper bags, the longitudinally compressive treatment step is adapted to impart a regular effect to the web in which fibers of the web are bent into a finely, barely, perceptible microcrepe texture, and the process demand level temperature is selected to dry the kraft paper to permanently set the microcrepe texture; the concentration of liquid that remains in the web is measured as it leaves the process and the liquid applied to the web prior to the longitudinal compressive treatment step is regulated on the basis of that measurement.

These and other features and advantages of the invention will be understood from the following detailed description taken in conjunction with the drawings wherein:

Drawings

Figs. 1 through 4 are highly magnified diagrammatic illustrations of a web being longitudinally compressed at various minute steps according to the invention;

Fig. 5 is a diagrammatic cross-sectional view of passage-defining components for providing the multiple minute steps;

Figs. 6 and 7 are views similar to Figs. 1 and 2 illustrating tensionless isolation achieved in the web prior to its longitudinal compression by means of successive lines of feed;

Fig. 8 is an end view of a machine adapted to employ the invention while conducting bladeless treatment of a web;

Figs. 9 and 9a are magnified views of the web-treating components of the machine of Fig. 8 illustrating the adjustment range of the components; Fig. 9b is a diagrammatic plan view of Fig. 9a and Fig. 9c is a side view of the primary member employed in the system of Figs. 8 and 9.

Fig. 9d is a cross-section similar to Fig. 9c showing a specially fluted final lip while Fig. 9e is a cross-section taken on line 9e-9e of Fig. 9d.

Figs. 10, 10a, 11 and 12 illustrate alternate means for establishing the retarding forces depicted in Figs. 1-7.

Figs. 13 and 13a are cross-sectional views at different degrees of magnification of an expansible air envelope arrangement for independent control of a stationary bladeless retarder member;

Fig. 14 is a highly magnified view of a polyester tricot flat knit fabric showing the effect of treatment according to the invention;

Fig. 15 is a view similar to Fig. 14 at less magnification;

Fig. 16 is a view similar to Fig. 15 of the same fabric treated with a different primary surface having a large number of minute steps;

Fig. 17 is a plan view showing the effect of the treatment on a fibrous nonwoven fabric;

Fig. 18 is a view similar to Fig. 17 of the effect of treatment upon another nonwoven web;

Fig. 19 is a perspective of an embodiment producing a plisse effect in a fabric; Fig. 19a shows the fabric; while Figs. 20 and 20a are cross sections taken at lines 20 and 20a on Fig. 19.

Fig. 21 is a diagrammatic view of a system for treating a synthetic textile fabric to take advantage of heat generated in the compressive treatment for heat setting the treatment effects permanently in the fabric;

Figs. 22 and 23 are diagrammatic views of the compressive heat-generating working action upon a fiber of the web; and

Fig. 24 is a view similar to that of Fig. 21 of a system for treating moistened paper in which heat generated in the compressive treatment is employed to dry and set the treatment in the paper.

Description of Preferred Embodiments

In Figs. 1-4 minutely stepped, polished stationary primary surface 10 lies over gripping surface 12 of driven roll 14 to form a confining passage in which compressive treatment of a web can occur. Each cross-section rectangle represents an equal weight of web.

The web has uncompressed thickness, t_o. At the left an initial part of the stationary surface presses the web against roll surface 12 with pressure P, to cause roll 14 to grip and carry the web forward at roll speed S. Progressing to the right are surface steps A, B and C, each followed by a respective polished land l_1, l_2 and l_3. Spacings of the lands from gripping surface 12 enlarge progressively by the discrete minor amounts Δt of the steps, to allow the web to elastically expand or to be compressionally thickened in discrete, minute increments. Thus the web increases from pressed thickness t_p to thicknesses t_1, t_2 and t_3. In this embodiment Δt at each step is less than one-third the original pressed thickness t_p of the web, e.g. Δt = .003 inch or less.

The stepped surface can thus be considered to define with the roll surface 12 a series of dimensionally similar but progressively enlarging axially aligned cavities I, II and III. Retarding means, not shown, apply retarding forces R to the web at the downstream end of the last cavity.

Figs. 1-4 show the treatments of different webs in different cavities. In Fig. 1, after web 16 has entered under stationary surface 10, downward pressure is concentrated at the edge of step A, as suggested by the arrows P. In this illustration, the first enlargement from t_p to t_1 at step A accomodates elastic expansion of this particular web, the enlargement being insufficient

to release the web from the gripping surface 12. Therefore, through cavity I the web remains longitudinally uncompressed and continues to move forward at roll speed S.

The edge at step B serves again as a concentration point for downward pressure against the driven roll.

As web 16 passes step B and enters cavity II in Fig. 1, it is confronted with an accumulated column of previously compressed web moving at a slower speed, S_r. (When treatment commenced the compressed column has accumulated back to this point from the right due to the retarding forces R.) At cavity II the further enlargement in space between surfaces 12 and 10 and the opposition provided by the retarded columnm cause the web to slip relative to the moving gripping surface 12 while the web is compressed longitudinally and thickened. The compressed state is indicated by the narrower-width rectangles that follow step B.

The column of thickened and longitudinally compressed web is moved forward from step B at retarded speed S_r. Forces providing this movement are the driving force of the untreated material being delivered to the compressional point at step B and the forward drag forces applied by the driven gripping surface 12 as it slides forward under the compacted column in cavities II and III. As the compacted column reaches step C, it encounters a further minor enlargement Δt. Because of the compressed state of the web at this point, the web elastically expands from t_2 to t_3 to fill this small change in passage height with no tendency for the web to fold into gross pleats. The further-thickened web moves through cavity III and past the retarding means, not shown. Beyond this point the longitudinally compressed web may be subjected to takeup tension to remove all but a desired degree of length compression while leaving in the web desired effects produced by the treatment.

The point at which longitudinal compression of the web occurs, denoted by letter O, is at step B in Fig. 1. If the treatment initially stabilizes at this step (as a result of the particular quality of web 16, its conditions of treatment and the relationship of the treatment surfaces), then despite subsequent variation in the web 16 or its conditions of treatment, the point of treatment O will tend to remain stably at step B for the following reasons. The web has been delivered with full speed to step B, the web thickness t_1 having been insufficient to permit the web to slip upon the gripping surface 12. Immediately after step B, however, due to the discrete expansion of chamber II, albeit small, the degree of pressure of the web against the driven gripping surface 12 has suddenly decreased by a step value. The retarding forces R, applied at the far end of the confining passage and acting through the column of compressed material thus suddenly can become dominant. These conditions cause the oncoming web to slip relative to the forward moving roll and to be longitudinally compressed and added to the compressed column.

Suppose, hypothetically, that point O began to migrate to the left. This would require the end of the compressed column to be forced leftward beyond step B. But the projected frontal surface 11 of the riser or step at B serves somewhat as a dam, and tends to block the thickened column from accumulating to the left. Furthermore, if the compressed column did start to wedge leftward under step B to enter cavity I, it would increase its downward pressure against the driven gripping surface 12 at this point. This would increase the forward driving force on this compressed portion of web, tending to propel the portion to the right at roll speed S and hence prevent such migration.

On the other hand, if one supposes that point of treatment O began to migrate to the right in cavity II, then a portion of untreated web would have to extend from point B at a distance to the right before reaching the end of the compressed column. This portion of web would be somewhat unconfined in thickness due to the stepped enlargement of cavity II, it would be subjected at the left to the drive forces being delivered at point B and it would be resisted to the right by the exposed end of the compressed column of web. With the untreated portion of web thus exposed to opposed feeding and retarding forces over a limited distance, and with this length of web being free to be thickened in the lateral direction by the stepped increase in cavity depth, the web will tend to compress longitudinally and thicken. The net effect of this action is to produce a tendency for the accumulated compressed column not to migrate to the right from step B.

Accordingly, over a considerable range of conditions, the step at B can serve to stabilize the point of original treatment.

The minor size of the step at which treatment occurs avoids any tendency for the web to form gross folds or have its faces impaired as it is treated. In the case of knitted and woven textiles in which the threads or yarns inherently undulate in the woven or knit pattern, the compressive action pushes the web together in its own plane, while tending to splay and crinkle the individual fibers, threads or yarns. In the case of nonwoven webs in which the fibers or other material are originally flat, the compressive action can produce microscopic undulations in the web itself, referred to as "microcreping".

Because of the range of conditions that can thus be tolerated by the construction of Fig. 1, normal variations in those conditions that may occur across a

wide width of web will not change the location of the point of treatment. Once the point of treatment is established at a given step it will appear to be "locked" to the step and treatment will stably occur in essentially a straight line across the full width of the web being treated.

For the example of Fig. 1 it had been assumed that the particular web 16 and relationship of the machine surfaces had caused the treatment to occur at step B.

Referring to Fig. 2, with a different web 16' or under different starting conditions, the initial point of compaction may occur at step C. This may happen for instance because web 16' is stiffer or more dense or its original thickness is greater or because of the manner in which the operator has adjusted the treatment surfaces. As the web has proceeded through dimensions t_p, t_1 and t_2 it has expanded incrementally but still engages the driven gripping surface 12 with sufficient force so that no slippage has occurred. At the time of exposure to the further stepped enlargement, at step C, however, the longitudinal compressive treatment conditions are satisfied and the web is compressed against the accumulated column of compressed web. Once established, the treatment will proceed with stability at step C, with frontal surface 11 of the step resisting rearward migration of the compressed column.

Thus the pair of minutely stepped cavities II and III can establish a stable treatment automatically over a wide range of conditions. In a sense the process determines for itself the step at which treatment will occur without need for precise control by the operator. Also, each cavity provides an important range of protection to the other in case conditions change to the extent to cause the point of treatment to shift. If the target setting during original adjustment of the machine

surfaces is defined as the setting in which treatment may occur at either cavity with equal likelihood, then if instability occurs when treating in either cavity, the direction of migration of point O will normally by toward the other cavity. As the compressed column reaches the step of the other cavity, only a short distance away, the treatment will restabilize for the reasons previously mentioned. Thus each cavity provides a unique safety feature for the other cavity and permits much greater latitude in treatment conditions and operator error than has previously been possible.

Referring to Fig. 3, with a much softer web 16" or with very different set-up adjustments, etc., it may sometimes occur that the requirements for longitudinal compression of the web are satisfied earlier and the treatment occurs at A. What has been said about stability with respect to Fig. 1 and 2 will now apply here. Rearward migration of the compressed column will be resisted by dam 11. After the web is longitudinally compressed at step A it proceeds through cavity I to steps B and then C. It encounters minor expansions to dimensions t_2 and t_3, but as in the earlier examples, such minor expansions, occuring incrementally, can properly confine the face of the compressively thickened web to prevent gross folds. As the web portions in cavities I, II and III are all in substantial axial alignment, drive forces now delivered at step A can assist in propelling the compacted column successively through the cavities and past the retarding means. The treatment in this case, as before, will proceed with stability. If the operator choses to define the target setting as one which causes treatment in cavity II, then instabilities of the point of treatment that cause migration of point "O" in either direction can be counteracted by an adjacent cavity. In this way the scope for tolerable operator error or variation in conditions can be even more extended.

The values chosen for Δt will depend upon the range of different webs and conditions to be accomodated. A guide for selection can be obtained from the dimensions of the point in a confining passage at which longitudinal compressive action can be made to occur, as observed in a gradually diverging prior art passage. This point may occur, for instance, where the spacing of the confining surface corresponds to the thickness of the original unconfined web, t_o. Also, the degree of shift in location of the point of compression that occurs with a standard change in passage depth e.g. of .001" can then be observed. From these observations appropriate step heights can be determined for the particular web which is to be treated.

It has been found in the practice of the present invention that minute step heights Δt of the order of approximately .003 inch at steps A, B and C are appropriate in many instances to stably establish the point of treatment.

In summary the features of Figs. 1-3 allow the web material, in a sense, to find for itself the minute step at which the degree of expansion is sufficient to allow it to slow and be treated. As changes in the conditions of the process occur, the point of initial treatment will tend to remain stable at that particular step but should conditions change considerably, the point of initial treatment may migrate to the next step. In such case the geometry is virtually a replication of the prior geometry to which the web was exposed, and the same treatment may continue with stability at the new step.

It is further found that in some pressure-sensitive materials, especially those that are soft and capable of being readily gripped by the driven surface, such as knit goods or a soft nonwoven sheet, an unusual multiple step treatment can be obtained. In this case there is a sharing of the total treatment amongst a

series of adjacent cavities. Referring to Fig. 4, as such a web makes the first transition at step A from dimension t_p to t_1, the amount of expansion allowed permits a first, minor level of longitudinal compaction to be achieved in cavity I, represented by O_1. The degree of treatment is self-limiting; the web compresses longitudinally only to a certain extent and the resulting thickening of the web causes the web to press against driven surface 12 sufficiently to cause the web to be driven forward, at speed S_{r1}, slower than the speed S of the roll surface, but faster than the final speed S_{r3} of the compressed column. (Supply tension T is overcome by the action at step A or at an earlier step if one is provided.)

When the partially compressed material reaches step B the same phenomenon occurs again. The web, as it enters the expansion to t_2 in cavity II again undergoes a longitudinal compressional change, represented by O_2, and reaches a more compressed state than it had in cavity I. Again, in a self-limiting way, the web stabilizes at a certain degree of thickening and continues forward at speed S_{r2}, a speed slower than that in cavity I, but faster than final speed S_{r3}. The web arriving at step B is tensionless, hence the treatment at this stage is isolated from any disturbance that supply tension can cause. At step C the web undergoes still another longitudinal change, represented by O_3, as it passes into dimension t_3 and slows to final speed S_{r3}. In this manner the web is subjected to three different treatments. The relative degree of treatment achieved at each cavity will depend upon the conditions at start up, and will tend to remain stable during the production run. Nevertheless, in the event of a substantial change in treatment conditions, a shift in proportion of treatment between the various cavities can occur without disrupting the process.

The incremented treatment of Fig. 4 exposes the web to compressional action over an extended length (still only a fraction of an inch), with vary desirable consequences. In cases where the treatment is strongly time dependent, this extended length enables a faster throughput speed. In cases in which the fabric is non-uniform as in the case of skewed or unusually large fibers or threads in certain materials, the staged compression provides more time for the web to adjust itself and for it to find a point where the treatment of the non-uniform parts can be smoothly completed while the web is still properly confined. In other cases, the staged treatment enables a smoother gripping surface to be employed and thus can reduce any tendency for the gripping surface to abrade the web.

Figure 5 shows machine elements which can achieve the cavities of Figures 1 through 4.

Surface 12 of driven roll 14 is plasma coated with tungsten carbide particles to provide a surface roughness preferably in the range of about 90 to 130 microinches A.A. (arithmetical average, as established by a profilometer).

Extending over the driven roll 14 from the left is a low-friction sheet-form primary member 18 which defines the steps A, B, and C and terminates at tip 19. A second sheet form member 20, serving as a backing plate, extends from the left, and lies face-to-face with sheet member 18. When certain types of retarding means are employed as described below, second sheet member 20 also extends beyond tip 12. Stationary member 18 is a planar sheet of blue spring steel SAE 1095 having nominal thickness d_o of .010 inch; sheet member 20 (or a number of sheets held face to face) is of the same steel and may have an aggregate thickness from about .010 to .030 inch depending upon the degree of pressures to be produced in the treatment cavities. Sheet member 18 has the series of steps formed in its under surface by machine grinding.

In a method of its construction the end portion of member 18 is first ground to remove .007 inch thickness, to establish the thickness d_3 at tip 19 of .003 inch, and to provide land l_3 of .050 inch length. In the next grinding step, the original thickness is reduced to thickness d_2 of .006 inch to provide land l_2 of length .050 inch. Thus step C, between lands l_2 and l_3 has a height of .003 inch. The final grinding step, to form land l_1 of length also of .050 inch, reduces the thickness to d_1 of .009 inch to establish the step height of .003 inch between lands l_1 and l_2 at B. Between the original surface and land l_1 step A has a height of .001 inch. (With a .012 inch nominal thickness member step height at A would be .003 inch.)

As indicated in Fig. 5, sheet members 18 and 20 are held together at the left on a stationary support 22 by means such as shown in Fig. 8. As shown in Fig. 5 members 18 and 20 extend horizontally, and are tangent to the top of driven roll 14 at center line ℄. A presser member 24 (see also Fig. 8) engages the upper surface of sheet member 20 at a point which lies distance X upstream from tip 19 of sheet member 18, and distance Y downstream from the center line ℄. (In the embodiment, X is .025 inch and Y .150 inch).

Backup member 20 distributes the pressure over primary member 18.

With the presser located over forward land l_3, the sheet members 18, 20 can deflect to cause lands l_1, l_2 and l_3 to converge slightly toward the surface of the roll, as shown in Fig. 6. This helps in establishing the edges at steps A, B and C as pressure concentration points.

In Fig. 6 there is a slight angle of convergence between the driven gripping surface 12 and each land 1 of the sheet member 18. The resulting

increase in downward force on the web 16 as it approaches each step is indicated by the increasing size of downward arrows P and the concentrated drive forces at the steps are denoted by horizontal arrows F. The resulting strength of the drive forces can overcome very strong tension forces T, as may be applied to the web to keep certain webs straight and unwrinkled when entering the treatment.

As a result of passing under the force concentrating edge at A the web can then emerge tensionless. The subsequent drive forces applied at steps B or C can thus be isolated from supply tension T and can act uniformly across tha full width of the web despite any variation in tension T that may occur across the width of the web.

The multiple drive edges thus improve both the driving and the treatment of the web and make the treatment immune to variations that hitherto have disrupted treatment.

The multiple stepped construction has other advantages as well. The concentration of perpendicular forces at the series of steps can "iron" the web to assure that the web uniformly engages the drive roll despite variations in thickness of the web. The multiple edges at the steps can have desirable softening effects upon such webs as papers and nonwovens by helping to break fibers bonds and free individual fibers, an action useful to prepare the web for subsequent treatment. Reduced friction provided by the stationary multi-stepped surface can reduce shear effects on the web and help the web move straight through the retarding passage.

Fig. 7 is similar to Fig. 6 except that a stationary frictional retarding surface 21 is diagrammatically shown beyond cavity III and the web is illustrated as a solid stiff sheet to be subjected to

microcreping. In the case illustrated here the enlargements of cavities I, II and III are all insufficient to permit longitudinal compression of the web. The web as it passes under the edge defining the final enlarged step D is thrust against an accumulated column of compressed material and longitudinal compression is shown to occur at this point, in the form of fine microcreping of the sheet. Here the arrangement of multiple concentrated lines of feed pressure provided by edges at steps A, B, C and D can assure uniform treatment of webs that are very difficult to drive, e.g., dense papers in the dry state.

Referring to Fig. 8 and the magnified views of Figs. 9 and 9a, the arrangement of Figs. 5 and 6 is illustrated in detail in conjunction with a member that provides a stationary frictional retarding surface. As seen in Figs. 9 and 9a a pair of .010 inch thick blue spring steel sheet form members 20 and 22 lie face-to-face with primary member 18 and extend beyond its tip 19 a distance E of the order of one half inch. The under surface of lower member 20 that extends beyond tip 19 is plasma coated with tungsten carbide particles to provide the desired frictional qualities (roughness preferably in the range of 90 to 130 microinch A.A., the same as gripping surface 12 of steel roll 14). Primary member 18 and sheets 20 and 22 are held together in holder 26 generally tangent with the top of drive roll 14 and are adjustable horizontally as a unit (horizontal arrows).

Presser member 24, a thick blue spring steel member, also held by holder 26, has a precisely formed square edge 24' that is parallel with the roll axis and is positioned horizontally between final step C and tip 19 of primary member 18. During adjustment, presser member 24 moves horizontally with the sheet members 18, 20, 22, compare Figs. 9 and 9a. The dimensions of sheet

member 18 may be as in Fig. 5 or as in Fig. 9c sheet member 18 may have an original thickness d' of .012 inch and the step heights Δt_1, Δt_2 and Δt_3 as well as tip thickness Δt_t may all be .003 inch; in other embodiments the step heights and land lengths can differ from each other.

In operation, web 16 is drawn from supply roll 28, Fig. 8, under supply tension T controlled by braked nip roll 30, the web is led over gripping surface 12 of roll 14, and thence to take up roll 32 which is driven by drive 34 so that its surface speed is maintained at a constant fraction (e.g. 85 percent) of the speed of roll surface 12.

Pressure of presser edge 24' upon sheet member 22 and 20 is transmitted to primary member 18, causing the lands l_1, l_2 and l_3 to converge in the manner described for Figs. 6 and 7. With the sheet members and presser adjusted to the position of Fig. 9, the sheet members are caused to curve about the roll beyond the vertical center line ℄. This establishes passage E in which retarding forces R are generated. The pressure of edge 24' positions the first part of the retarding surface 21 close to the roll surface 12 while downstream portions diverge slightly as shown. The setting of Fig. 9 is suitable for a range of soft and easily retarded webs such as woven and knitted textiles.

In the position of Fig. 9a, the sheet members and presser have been drawn back together to position the presser member on the vertical center line ℄. Because of the roll geometry this causes the retarding surface to press with greater force against the web, suitable e.g. for treatment of stiff webs, such as papers, nonwovens, denim woven fabric and the like. Fig. 9b shows in plan view the relation of the presser edge 24' in advance of the minute steps A, B, and C for achieving the desired convergence of the lands l_1, l_2 and l_3.

In Figs. 9 or 9a, and in intermediate positions, the treatment can proceed as previously described, with the steps allowing the web to seek its own place to compact and with the initial minute step or steps serving to define drive pressure lines.

Referring to the alternative embodiment of Figs. 9d and 9e in this instance the final lip of the cavity member is specially fluted to impart a slight linear pattern much like a pinstripe to the fabric. This can mask defects in the treated fabric or provide a desired pattern. In the embodiment shown the lip is knurled with a 22 per inch pitch, P, knurling tool with the resulting convex side of the lip engaged with the fabric. Advantageously the element defining the retarding surface is somewhat deformable to accommodate the high points of the lip. The web as it emerges is forced into the periodic depressions at these points, to provide the desired pattern. The effective thickness of the lip t' is greater than in the nonfluted case, see Fig. 9c.

The invention can be employed with other retarding means of which Figs. 10-12 are examples. In Fig. 10 a retarder blade 40 is positioned to divert the web away from roll surface 12. A sheet-form member 42 lying over primary member 18 has an extension 42a which bends to follow the surface of blade 40, to form therewith a retarding passage. In known manner, (see our U.S. Patent 3,260,778) resilient nipping action in the retarding passage can cause a compacted column of web to extend back to and past the tip 19 of the primary member 18, to apply retarding forces R.

Sheet member 42 may be blue spring steel of .010 or .020 inch thickness. A notch 44 is provided in its upper surface slightly beyond tip 19 of primary member 18. This notch provides a hinge point which allows the downstream part of member 42 to freely bend

to the contour of blade 40, to present a smooth stable surface to the web, while allowing the upstream part of member 42 to have sufficient strength and uniformity to provide the needed backing to the primary member 18.

In the version of Fig. 10a, the tip of the retarder blade is inserted under the last land l_3 of the primary member. In this manner the last portion of the primary member itself makes the angular transition and serves as the flexible retarder in opposition to the retarder blade 40. The advantage is that the web material may be more tightly confined than in Fig. 10 to produce a finer treatment.

In Fig. 11 a driven roll 14' having circumferential grooves spaced periodically along its length is shown in conjunction with a comb retarder 42. The teeth of the comb are inserted in the grooves and ensure that the web is smoothly diverted through a path similar to that of Fig. 10. Despite the presence of the grooves in the roll, the minute steps of the primary member 18 serve their functions as described above. In the embodiment shown, a very fine crepe texture is applied to the web.

In Fig. 12 a retarding roll 15 is mounted in parallel over drive roll 14. As indicated by the arrows, surface speed S_1 of retarder roll 15 is slower than speed S of drive roll 14. Retarder roll 15 has a web gripping surface which engages the web as it emerges from under primary member 18. The slowing action of retarder roll 15 on the web causes the retarding forces R to be presented at the tip 19 of the primary member.

Figs. 13 and 13a illustrate the possibility of use of a relatively broad presser surface 24' which spreads the pressing force. The corners A, B, C still act to concentrate the drive forces in definite lines. This structure also enables a substantial increase in bulk of the final treated fabric while retaining the fineness of treatment.

Also in Figs. 13 and 13a the control for the retarding forces is decoupled from the presser 24 in a system the same as in Figs. 8 and 9, with the following exceptions. Sheet member 20a (.010 inch thick blue spring steel), which acts as a backing plate for the primary member 18 and has a downstream section 20b that provides the retarder surface 21, also has a decoupling hinge-forming notch 23 in its upper surface (notch .005 inch deep, .035 inch wide). The notch is slightly downstream of both presser 24 (dimension H, 0.3 inch) and tip 19 of primary member 18 while it is upstream of retarder section 20b. A device 44 which includes an air-expansible envelope 42 provides the pressure control with which the retarding surface 21 is pressed against the web. This device includes a stiff sheet form member 40 (.020 inch thick, blue spring steel) held by holder (26, Fig. 5) face to face with sheet member 20. In the region of primary member 18, member 40 serves as a reinforcement to transmit downward pressure from presser 24. The extension 40a beyond presser 24 (dimension E, 2 1/2 inches, same for 20b) serves as a reaction member to direct the effect of air expansible envelope 42 downward against retarder 20b. The envelope 42 is formed of a flexible, impermeable substantially inextensible sheet, (polyester film .003 inch thick). The top of the sheet, 42a, extends along the undersurface of member 40. At the free end of member 40, at the right, the sheet extends down and the bottom part of the sheet extends back along the upper surface of retarder member 20b. Parts 42a and 42b are captured and sealed at the left between members 20a and 40. The envelope extends parallel to the axis of roll 14 throughout the width of the machine and terminates at ends that are suitably sealed. An air supply nipple 46 connected to the envelope through plate 40a is connected to variable air pressure control 47.

In operation, the assembly is brought into position over the roll, and with no air pressure in envelope 44 the presser member 24 is caused to apply its downward force. With roll 14 turning and with little or no retarding force being applied at retarding surface 21, the condition of feed can be inspected to ensure that primary member 18 is feeding properly. The operator can then gradually apply air pressure to the expansible envelope 44 to press retarding surface 21 into engagement with the traveling web until suitable compressional treatment is obtained.

Any non-uniformities in the expansive action of the air envelope, such as a tendency for the bottom of the envelope to become round when expanded, are mediated by the intervening cantilever spring sheet member 20b. This member bends down gradually in a curvature approximating the curvature of the roll, to provide the desired controllable retarding action.

By such a decoupling arrangement, it becomes possible to place the presser 24 in the optimum position for achieving the desired drive, preferably with tensionless isolation between multiple drive lines, and the retarding forces can be independently varied, without danger of choking the flow because of undue downward deflection of the tip 19 of the primary member 18.

Referring to the highly magnified photographic view of Fig. 14 and the less magnified Fig. 15, during the treatment of a typical polyester warp knit fabric using the system of Figs. 8 and 9 the treatment was stopped, the treatment surfaces were allowed to cool with the web in place, and the web was then photographed. The impressions of the minute steps A, B, C, D can be seen in this photograph, and are denoted by corresponding letters. The resulting treatment corresponds to the description of Fig. 4. Prior to step

A, the untreated web U is longitudinally uncompressed. It was exposed to slight supply tension. Following the impression left by step A the web remains essentially uncompressed but the yarns appear slightly thickened, indicating that the tension on the web has been released and that the web is relaxed. At step B a high degree of longitudinal compression can be seen to have occurred, and at step C some additional longitudinal compression has been added. Beyond the tip D of the primary member the web appears to have the same degree of longitudinal compression as it did prior to reaching the tip.

Referring to Fig. 16, a similar polyester web was treated with a primary member having 8 minute steps. The imprint of a number of these steps is seen in the view of Fig. 16. Most of the longitudinal compression can be seen to have occurred in two adjacent cavities following the imprint in the untreated web of a number of the prior steps.

Fig. 17 is a photographic view magnified to the same scale of Figs. 15 and 16 of a nonwoven web, known as "spun bounded". (In manufacture of this web, thermoplastic monofilaments layed randomly in a mat are then calendared under heavy pressure and heat to bond the crossing fibers together without use of an adhesive agent.) This web was longitudinally compressed according to the invention, with the results being similar to a combination of the results described for Figs. 4 and 7. During passage of the web from minute step A to the tip D, the fibers were gathered longitudinally and reoriented. Following tip D a minute microcrepe texture was added. The untreated web had been stiff and harsh. The treated web was observed to be pliable, conformable (important for its use in upholstered furniture) and, unlike the untreated web, it made no noise when flexed.

In Fig. 18 there is a view similar to Figs. 15-17 of a nonwoven web (a tablecloth material) formed by wet laying of cellulose fibers on a paper making machine, using a synthetic resin binder. In this case the effect of the steps of the primary member has been to apply multiple discrete lines of feed pressure. At step D, the end of primary member 18, an extremely fine microcrepe effect was formed as can be perceived in this magnified view. The difference in the two letters "X" which appear in the photo are a measure of the degree of lengthwise compression.

Besides the capability of uniformly treating a wide width of web, another capability of the invention is to produce longitudinally compressed fabric in stripes. Referring to Figs. 19, 20 and 20a stripes of compressed fabric are shown at 50 while uncompressed portions lying between the stripes are controllably gathered in bubbles 52 to produce an overall plisse effect. For the striped compressed portions, the treatment surfaces are as shown in Fig. 20. The primary member 18 corresponds to Fig. 5. An inextensible, stationary retarding sheet member 20' defines the retarding surface 21 in accordance with Fig. 9, but it is in the form of spaced fingers 54 that have width of the desired stripes of compression, see Fig. 19. The retarding surface 21 produces retarding forces at the end of the primary member 18 while longitudinal, compressive treatment for these stripes occurs at point O, at step B. In the case of treating a tightly woven cotton fabric which is loaded with inks and synthetic resins, the friction surface 21 is chosen to be quite aggressive in order to sufficiently engage the web. Emery cloth can be used as the retarder surface in this case.

For forming the areas of uncompressed bubbles, the retarding sheet member 20' has cutouts at 56, Figs. 19 and 20a which extend from the forward edge, back under presser member 24. This sheet member 20' has a thickness d_2 corresponding to the height of the desired bubbles. Sheet member 22, lying over retarding member 20' is continuous across the full width of the machine. Where it overlies the cutouts 56, the sheet member 22 defines with gripping surface 12 of the roll, bubble gathering chambers, and member 22 serves to limit the height of the bubbles that are formed. To summarize, the operation, as the web is longitudinally compressed at point O in line with the retarding fingers, Figs. 19, 20, the adjacent web is caused to gather in the desired bubbles in the gathering chambers as shown in Figs. 19 and 20a.

Because of the high degree of longitudinal compression that is applied in the striped regions, and heat setting, the final fabric retains the pattern shown. It will be understood, however, that during the treatment a much greater degree of longitudinal compression can be applied to the web than may be allowed to remain after the web is withdrawn from the treatment under controlled tension conditions.

An important product formed by the technique illustrated in Figs. 19 and 19a is an inexpensive knit fabric. By virtue of the limited amount of spring-like resistance provided by limited areas of permanent compaction in spaced apart stripes, see Fig. 19a, the fabric provides a ready stretchiness that in clothes permits wearer comfort. In the case of child's clothes, the clothes can expand to fit as the child grows without ever exerting undue or uncomfortable tightness to the child and without being loose. A specific example is a tubular knit, 100 percent polyester fabric, having alternating monofilament and multifilament yarns, which

is slit and processed in the open width. It has an untreated weight of 6.3 square yards per pound and a compacted weight of 4.6 square yards per pound. The fabric has 22 courses per inch before compacting and averages 27 courses per inch after compacting. Heat setting of the striped compaction by methods described below ensures that clothing made from such cloth is highly stable and retains its shape after a number of washings.

USE OF COMPRESSIONAL TREATMENT TEMPERATURE RISE

Webs usually are treated to render them highly plastic before entering a longitudinal compressive treatment. It is found if the treatment is limited to retain a degree of toughness in the substance of the web, the compressive treatment can be employed to generate heat through dissipation of work energy to meet a temperature demand of the web treating process. For instance prewarming of a plastic web can be limited to retain the desired toughness or the moistening of paper can be regulated for this purpose.

The term "work" as here used refers to the definition in physics, of force acting through distance.

The relationship of the plastic condition of the web to the degree of mechanical heat generated can be suggested as follows. Assume three progressively increasing levels of plasticity Pl_1, Pl_2 and Pl_3. Such levels can be assumed for instance in a thermoplastic textile web that has been heated respectively:

--to a low temperature at which there is little physical change from ambient conditions, so that the fibers are still mainly elastic (small degree of plasticity, Pl_1);

--to a moderate temperature in which the fibers will structurally yield under the conditions of compressive treatment rather than elastically deform, but the degree of structural toughness that remains requires considerable work to be performed to deform the fibers (moderate plasticity, Pl_2);

--to a high temperature approaching its softening point where the fibers are highly plastic and require little work for permanent deformation (high plasticity, Pl_3);

In the case of kraft paper such conditions of plasticity could correspond to a paper web that has been moistened respectively:

--to a low moisture level, for instance the ambient moisture level of 5% by weight (compared to the dry weight of paper), in which the paper is stiff or elastic and is subject to sudden columnar collapse with breakage of fibers (Pl_1);

--partially moistened, e.g. to 20% by weight, to a level in which the web is subject to permanent deformation but retains structural toughness (Pl_2);

--to a high level, e.g. 50% by weight, so that it is limp and readily deformable (Pl_3).

These levels of plasticity determine the amount of heat that can be mechanically produced during the longitudinal compressive treatment.

At condition of plasticity Pl_3 in which the web is soft, the mechanical treatment may impart little work and there will be an insignificant heat rise attributable to work in the web. For the web which has low plasticity Pl_1, work that is expended may go mainly into elastic deformation of the web which does not dissipate heat, or alternatively the web may suddenly buckle under compressional forces, and again there may be insignificant conversion of work into heat energy. However, in an intermediate case, Pl_2, the

fibers or other substance of the web are capable of being desirably deformed by yielding under compressional treatment conditions, but the yielding occurs with a degree of internal resistance that requires "work" on the web to be dissipated. During the expenditure and dissipation of such work, the interior substance of the web (or at least the component fibers at the points in which the microcreping action is concentrated) can be correspondingly heated significantly due to internal friction. This friction may occur because of movement of the individual fibers against one another in the web during the fiber rearrangement of the compressional treatment as well as because of internal friction within the body of the tiny fibers themselves. We have discovered that the amount of such heat can be depended upon to meet a process demand level of heating.

The number of factors affecting the desired plasticity or toughness for reaching a desired temperature level vary from material to material. Still, for a given material, these factors are partly known, as from tables of properties for thermoplastics, and can be determined, e.g., by subjecting a selected web to test using a standardized laboratory microcreper system and conducting a simple parametric analysis by progressively differing moisture level, temperature level, and other parameters of the process.

For kraft paper, for instance one can determine moisture to be the principal factor affecting plasticity (and temperature a secondary factor) and the amount of moisture (and the temperature if desired) of the paper can be regulated (for various weights of kraft paper to around 20 percent total moisture by weight) to achieve a suitable level of plasticity for this aspect of the invention.

In the case of polyester, which has a heat set temperature of around 350°F, an optimum web temperature to establish the desired limited plasticity is around 250°F.

For treatment of such synthetic materials to obtain permanence of longitudinal compressive treatment effects by self-generation of heat the work-generated temperature rise is not only plasticity-dependent but is also dependent upon the speed at which the process is conducted. Over a range, a higher temperature level is reached the faster the process is conducted. We believe this to be due to heat loss to the relatively cool driven roll, as this roll must be kept at a low temperature in order to maintain the desired limit to plasticity of the web as it enters the treatment.

Furthermore, at slow speeds frictional heating of the substance due to sliding of fibers upon each other or due to internal friction in the thermoplastic substance may cause less temperature rise.

In the case of treatment of polyester and nylon webs we have found that the web will not self-heat to the desired level for establishing permanence of treatment if treatment speeds are in the range of 5 to 10 yards per minute. As the treatment speed is increased, a higher steady state temperature is reached; upwards of 10 yards per minute, perferably above 15 yards per minute for nylon or polyester tricot, the process demand level is exceeded and the compressional treatment effects can be permanently set by conversion of work to heat energy.

For different treatments or web materials, one can, through operating over a range of speeds and examination of the results, readily determine the minimum speed to operate for a given process.

An upper speed limit may similarly be established for a material. For instance, if the web passes through the machine too quickly the mechanical treatment may to some extent result in elastic shock rather than permanent deformation (mechanical working) of the material. In this case too high a speed may not heat the web as much as a lower speed; in other cases, too high a speed may result in overheating and production of unwanted glazed characteristics or the like in the material being treated, or may not allow adequate visual inspection during the process.

According to the invention, specifically in the treatment of polyester tricot material using the bladeless microcreper process as described above, the preferred operational temperature for the driven roll is in the range of 220 to 280°F, the optimum usually between 240° and 280°F, and the preferred operational speed is in the range of 15 to 50 ypm, preferably between 15 and 20 ypm. For nylon tricot the same speed range applies with the temperature range for the roll of 240° to 300°F and the optimum usually between 270 and 280°F.

It is discovered that by observing these conditions the compressive treatment of the material is automatically permanently set by the compressive treatment itself. An additional step of passing the compressively treated web through electric or oil or gas-fired heat-set ovens on costly tentering frames may thus be avoided and the compressional treatment can be the last treatment of the fabric. Furthermore, the level of preheating of the web prior to the treatment, avoiding introducing the web at a high level of plasticity, gives a web that is must easier to handle, distortion tendencies are avoided and a softer and better treatment can be obtained.

As also noted, this heat generation and use aspect of the invention also has particular application to the microcreping of paper. Heretofore, in creping kraft paper for the purpose of increasing its burst strength, it has been customary to add moisture to bring the paper to a plastic condition, to crepe the paper, and then to pass it through oil-fired hot dryers to remove the moisture. The drying step has been a very detrimental cost.

According to the invention, the microcreping process and the moisture content of the paper are appropriately balanced so that the mechanical process itself raises the paper substantially to the drying temperature, and large driers are no longer needed. A proper roll of microcreped paper can thus be obtained by directly winding the output of the microcreper or similar processor.

Specific Embodiments

Fig. 21 shows a system for conducting the longitudinal compressive treatment of relatively cool thermoplastic webs to achieve permanent setting without need of separate heat setting following the treatment. The driven roll 14, holder assembly 26, primary 18, retarder 20', and backing plate 22 are constructed as shown in Figures 8 and 9 and the cross-section of Figure 20. Roll 14 is driven by variable speed motor 80 via belt 82 and is heated internally by a flow of heated liquid from source 84 to establish a stable relatively low temperature h_r at roll surface 12. Presser 24 presses the primary 18 and retarding member 20' down against the top of roll 14. A web supply roll 86 is rotatably mounted on axle 88 in slot 90. Slot 90 is slightly inclined and ensures that supply roll 86 constantly bears against the drive roll 14 as roll 86 diminishes in size. Web is transferred from roll 86 directly to driven roll 18 as driven roll turns in

direction S. Means not shown maintain the axis of roll 86 parallel with the axis of driven roll 14. Brakes 92 acting on opposite ends of axle 88 retard the rotation of supply roll 86 to apply supply tension T to the web 16 as it approaches the treatment head. Treated web 16_t, soon after it emerges from under the retarding surface 21, leaves roll 14 and engages in succession idler rolls 94 and 96 and then passes under winding roll 98 to take-up roll 100. Take-up roll 100 has its axle mounted in angled slots 102 similar to slots 90 for the driven supply roll, allowing rightward and slightly upward movement of the take-up roll 100 as it grows in size while ensuring its contact at all times with winding roll 98. Winding roll 98 is driven via belt 104 and via positive infinitely variable drive mechanism 106, which in turn is directly driven via belt 108 by driven roll 14. Winding roll 98 drives idler 94 by belt 110 and idler 96 by cross belt 112. The ratio of the drives of the idler rolls 94, 96 relative to winding roll 98 is preset to be slightly (e.g. 5%) slower than the surface speed of the winding roll. The positive infinitely variable drive mechanism 106 can be adjusted so that the winding roll will turn at the desired speed ratio relative to the surface speed of driven roll 14. Differences in speeds may range from a few percent to as much as 15 or 20 percent, depending upon the desired treatment for the fabric. It will be understood that in the treatment cavities the web is compressed to a much greater degree than this, and then much of the compression is drawn out by the winding roll 98, to achieve the desired percentage treatment. Idler rolls 94, 96 and winding roll 98 are internally colled by a flow of cooling liquid from source 114.

In a typical treatment, chosen for illustration, the supply roll 86 comprises a warp knit nylon tricot fabric of thickness between .009 and .010 inch, formed of 40 denier yarn, each yarn formed by e.g. 12 fine monofilaments, there being 49 courses (lengthwise) per inch and 48 wales (crosswise) per inch. For this web the heat set temperature is of the order of 350°F. The heat source 84 is regulated to maintain the roll surface at temperature h_r of 280°. Tha cooling liquid at source 114 is maintained at 35°F. The retarding member 20 provides retarding surface 21 in the form of the plasma coated particles on a spring steel substrate of .010 inch thickness, the coated surface presenting a surface roughness of between 110 and 120 micro inches AA. Dimension X (see Figure 5) is set in the range of .020 to .125 inch (the smaller dimensions being employed when the corners of the steps are slightly rounded to provide less drag on the web). The extent E (see Figure 9) of the retarding surface beyond the tip of the presser 24 is 1/2 inch.

Under these conditions when driving the driven roll 14 at speed S in the range of 15 to 20 yards per minute, the web as it is transferred from the supply roll 86 to driven roll 14 has temperature h_o significantly above ambient temperature because of the heating of a certain depth of roll 86 due to its continuous contact with roll 14. As the delivered layer of web travels with heated gripping surface 12 of roll 14 it quickly rises in temperature so that its temperature h_2, before its treatment, corresponds with that of the roll, h_r. A sudden rise in temperature of the web to h_3 (or at least of the component fibers being bent) occurs e.g. at treatment point O. Fig. 1, as a result of the rapid mechanical working of the longitudinally extending yarns as illustrated in Figures

22 and 23. As shown in Figure 22, an individual longitudinally extending fiber of the fabric is exposed to a retarding force R and a drive force F. This fiber, at the preselected temperature of the roll, retains structural toughness to resist bending and requires work to be performed as it is bent at *g* to the crimped condition of Fig. 23. Heat is generated at each crimping point *g* in the fibers (the exact points where the heat setting effect is subsequently required), these crimping points being concentrated across the machine at treatment point O. With the speed of the process maintained over a certain minimum, e.g., speeds exceeding 10 yards per minute, preferably above 15 yards per minute, but below 30 yards per minute to allow for inspection, the aggregate effect of the multitude of heat-generating crimping incidents produces a sudden heat rise that can elevate these points in the fibers to temperature h_2 to cause permanent setting (even through untreated fibers such as those extending crosswise of the fabric may not be so much affected).

Friction at the retarding surface 21 and roll surface 12 can have added heating effects. Multiple cavity treatments may extend the time over which the heating occurs.

Immediately after leaving the retarding surface 21, for instance after only 1 or 2 degrees of rotation of the roll 14, the web leaves the roll and in succession engages chilled rolls 94, 96, and 98, and then is wound on roll 100. Through the course of these engagements, the web is chilled rapidly to ambient temperature to establish the set condition.

Tests have shown that the treated web has been changed in a permanent way in very desirably qualities. As it came from the supply roll it was a typically inexpensive and harsh nylon tricot having a slick and undesirable surface, and characterized by the words

"plastic", "sleezey" and "optically transparent". Following the treatment, with only a few percent change in length, the fabric has undergone drastic permanent change. It has become much more opaque and soft and is characterized by the words "buttery" and "good hand and feel" owing to the crimped nature of its component fibers. In its treated condition the fabric is desirable for use in lingerie. Successive wash tests have shown that the treatment is permanent with no undesired lengthening of the fabric following repeated washings.

The unique self-heat set treatment illustrated has many desirable features. The web is preheated by contact with the driven roll, and moves over to it directly, with no chance to wrinkle or neck down in width more than a small percentage. By allowing the web to remain at a relatively low temperature until it reaches the treatment, there is no chance of undesirable melting or glazing of the web surface and thus no damage to the web. By the use of chilled rolls immediately following the treatment the web is suddenly shocked to a low temperature which improves the stability of treatment. Since the web is rewound after only a few feet of travel from the driven roll 12 there is little chance for necking-in of the fabric following treatment. Also the disadvantageous costs of separate heat setting and tentering are avoided and the entire process is conducted in a very energy efficient manner.

The treatment just described is useful for woven fabrics made of synthetic thermoplastic yarns and also is useful on non-woven webs when formed of thermoplastic fibers or substances of similar quality.

The system described takes advantage of the wide range capabilities provided by the minutely stepped primary surface 18. As heat set requirements or the nature of the treatment requires change in the

temperature of the roll to change the temperature and plasticity of the web, such changes can be automatically accommodated by the actions described above in respect of Figs. 1-4 and 6 and 7. Advantageously, to provide still further control, the hinge and air envelope features described in connection with Figs. 13 and 13a, are employed in the automatic heat-set system.

In certain instances, however, e.g. with specific readily treatable materials, it is possible to employ previously known treatment cavities for conducting the new automatic heat-set process.

Fig. 24 shows a system for longitudinal compressive treatment or microcreping of a kraft paper web which controls moisture application to achieve the needed limited plasticity. Subsequent removal of the conditioning moisture occurs without need for a special large dryer.

The driven serrated roll 14', holder assembly 26, primary 18, backing member 42, 42a, presser 24, and retarding comb 43 are constructed as shown in Fig. 8, as modified by Fig. 11. Roll 14' is driven by motor 80. Presser 24 presses the primary 18 and backing member 42 down against the top of serrated roll 14'. A web supply roll 120 on unwind stand 124 supplies paper web to be treated while rewind stand 126 rewinds the treated web onto take-up roll 128. From supply roll 120 the untreated web passes idler 122 and moistening unit 132 (Dahlgren Liquid Application System, Dahlgren Manufacturing Company, Dallas, Texas) and proceeds to bowed spreader roll 134, to idlers 136 and 138 and thence to the serrated driven roll 14'. The microcreped web upon leaving the treatment cavity passes over idler roll 140 and thence to the rewind stand 126. In the rewind stand the web passes over a set of idlers to driven winding roll 142 and thence to the take-up roll 128. Roll 128 is constantly driven at the surface speed

of the winding roll in the manner mentioned for Fig. 21. First and second moisture detection devices 144 and 146 (Quadrabeam moisture meter from Moisture Systems Inc., Hopkington, Massachusetts) are employed. Detector 144 detects the moisture of the untreated web following the moistening device 132 and preceding the compressive treatment. Detector 146 detects the moisture content of the treated web immediately before it is rewound. The detection signals from detectors 144 and 146 are applied to control device 148. The control device 148 generates a moisture command signal which is applied to control unit 150 for regulating the amount of moisture applied by unit 132 to the untreated web to maintain the added moisture at a level which is removed by the heat rise of the compressive action, while maintaining moisture level M_2 in the predetermined range of plasticity for achieving the desired treatment. Signal over lead 152 is applied by the control unit to the motor 80 for varying the speed of the web through the machine, as here again more heat can be generated, the faster the treatment occurs. Additional moisture detector 154 and accessory heated roll 156 may be employed following the treatment and preceeding the rewind mechanism.

The moistening device is constructed to ensure that moisture applied to the web is uniformly distributed through the web thickness (where for any particular web the moistening unit is inadequate, accessory devices such as a steamer or a heated roll following the moistener can ensure that the moisture permeates through the entire web thickness.)

The moisture profile of the web as it passes through the treatment varies as follows. The moisture content M_0 of the untreated web is due to ambient conditions, as the web comes from the supply roll, e.g. 5% moisture by weight. The moisture content M_1 following the moistening unit has increased by an amount

required to reach the plasticity range needed for he particular compressive treatment (range determined by practical test for any particular web and regulated by control unit 148 in accordance with control techniques that are known). With kraft paper, (60 pound weight paper) the moisture content at M_1 may range around 20%. The moisture of the web M_2 as it travels over the driven roll 14' to treatment continues or may drop somewhat from the M_1 level. Heat generated as the microcreping treatment occurs at the cavity (treatment speed e.g. 1000 fpm) is imparted to the web, and rapidly drives off excess moisture. Thus the moisture content of the web at M_3, following the treatment a distance allowing for the generated heat to evaporate the moisture, is substantially decreased. From there the web can be wound directly on the take-up roll 128 with perhaps somewhat higher moisture content than in the original supply roll (resisdual excess moisture can leave the paper under ambient conditions in a reasonable time due to the relative porosity to air provided by the microcreped condition of the paper). During operation if detector 146 reads too much moisture it will call for higher speed of the machine (to increase the heating effect of the treatment cavity) or for less conditioning moisture (if the lower limit of the conditioning range of perceant moisture has not been reached.)

Especially for use in humid days, it is desirable to include a simple auxiliary heat system, e.g. heated roll 156, to remove additional moisture to bring M_4 to the desired level. This system may be used in other situations, e.g. where it is desired to operate roll 14' at constant speed or at speeds unregulated by moisture. In such case detector 146 is used in the control circuit for auxiliary heated roll 156 in accordance with usual control technology.

Kraft paper treated according to the invention can receive a permanent fine microcrepe texture which resists being pulled out when subjected to loads (requires substantial work to be performed). For instance when the paper is used to form a bag for merchandise, in comparison to untreated paper, much more work must be performed by the load in respect of the treated paper before the bursting limit is reached, hence the paper is stronger for its intended purpose. The process is extremely energy-efficient, as a relatively small amount of moisture is required to condition the paper for treatment and at least a substantial portion of this added moisture is removed as the result of the mechanical longitudinal treatment itself.

For the above system for treating paper and the like, the minutely stepped primary surface, supra, and in particular the multiple lines of feed and the isolation of the treatment from web supply tension as described in connection with Figs. 6 and 7 is very advantageous to the process, and enables the plasticity of the web and other starting conditions to be varied over an operating range to accommodate the needs of the self-drying aspect of the process.

In an alternate embodiment the bladeless machine, as depicted in Figs. 22 and 22a, is advantageously employed in the treatment of kraft paper.

What is claimed is:

1. In a method for longitudinal compressive treatment of a web comprising engaging the web on one side by a stationary surface and on the other side by a driven gripping surface, using the stationary surface to press the web against the driven gripping surface in a drive zone to drive the web forward in the longitudinal direction, downstream thereof using the stationary surface to confine the forward-driven web against the driven surface in an enlarged confining zone, and retarding the web downstream of the confining zone to cause compressed material to accumulate in the confining zone so that the untreated material driven into the confining zone longitudinally compresses against previously compressed material, the improvement comprising exposing the forward driven web successively to a series of minor, discrete stepped enlargements of the space between the stationary and driven surfaces that increase progressively along said travel direction in minor amounts relative to the thickness of the web, thereby presenting to the traveling web a series of adjacent, dimensionally similar zones in which longitudinal compressive treatment can occur, whereby, in the presence of change in treatment conditions that tend to shift the place where compressive treatment occurs, the major point of treatment can occur alternatively in different of said series of adjacent similar zones.

2. In a method for longitudinal compressive treatment of a web being supplied under tension comprising engaging the web on one side by a stationary surface, and on the other side by a driven gripping surface, using the stationary surface to press the web against the driven gripping surface in a drive zone to drive the web forward in the longitudinal direction, downstream thereof using the stationary surface to confine the forward-driven web against the driven surface in an enlarged confining zone, and retarding the web downstream of the confining zone to cause compressed material to accumulate in the confining zone so that the untreated material driven into the confining zone longitudinally compresses against previouslycompressed material, the improvement comprising

exposing the web to at least two discrete successive stepped enlargements of the space between the stationary and driven surfaces, employing the first step to defining a concentrated drive pressure point to press the web tightly against the driven surface to apply drive force to the web to draw the web forward and overcome the supply tension, confining the portion of said web extending downstream from said first step to continue movement with the drive surface in a relatively tensionless state, essentially without compaction or slippage of the web relative to said driven surface, using the following second step to enlarge the height between said stationary surface and driven surface to present to the web said enlarged confining zone in which longitudinal compressive treatment can occur, and using

the edge of said second step to defining a second concentrated drive pressure point to press the web against the driven surface to apply drive force to the web, to drive the tensionless web forward against said accumulated compressed material to cause said longitudinal compressive treatment.

3. The longitudinal compressive treatment method of claim 2 comprising exposing the forward driven web beyond said first step successively to a series of minor, discrete stepped enlargements of the space between the stationary and driven surfaces that increase progressively along said travel direction in minor amounts relative to the thickness of the web, thereby presenting to the traveling web a series of adjacent, dimensionally similar zones in which longitudinal compressivetreatment can occur, whereby, in the presence of change in treatment conditions that tend to shift the place where compressive treatment occurs, the major point of treatment can occur alternatively in different of said series of adjacent similar zones with the web proceeding substantially tensionlessly between said first step and the step at which said major treatment occurs.

4. The longitudinal compressive treatment method of claim 1, 2 or 3 wherein said stationary surface presents to said web a series of essentially planar and polished lands extending in the direction of web travel and discrete, minor riser portions at said steps, with the riser portions extending at substantial angles to said planar lands.

5. The longitudinal compressive treatment method of claim 1, 2 or 3 wherein said steps are of the order of 0.003 inches height.

6. The longitudinal compressive treatment method of claim 5 wherein the portions of said stationary surface extending between adjacent steps are of the order of 0.050 inches in longitudinal extent.

7. The longitudinal compressive treatment method of claim 1, 2 or 3 adapted for treatment of a predetermined web material, wherein the height of each step is no more than about one third of the thickness of the material.

8. The longitudinal compressive treatment method of claim 1, 2 or 3 wherein said stationary surface presents to said web at least three of said steps that bound longitudinal compressive treatment zones.

9. The longitudinal compressive treatment method of claim 1, 2 or 3 comprising employing over a driven roll surface a metal member to define a minutely stepped surface to provide said stepped enlargement of space, and orienting said member so that lands of the surface extending between steps converge relative to the driven roll surface in the direction of the travel of said surface.

10. The method of claim 9 comprising employing a sheet member of spring metal to define said minutely stepped surface, and deflecting said member about said roll to provide said convergence.

11. The longitudinal compressive treatment method of claim 1, 2 or 3 wherein said retarding is provided by a surface following said confining zone, in which there is a minor step in the region of transfer of the web from said confining zone to under the retarding surface without substantial change in passage dimension.

12 The longitudinal compressive treatment method of claim 11 wherein said step is of the order of 0.003 inch.

13. The longitudinal compressive treatment method of claim 12 wherein said retarding is provided by a stationary retarding sheet overlying said drive surface and defining therewith a retarding passage, the confining passage serving to direct the web into said retarding passage in a direction substantially parallel to said retarding surface.

14. The longitudinal compressive treatment method of claim 1 wherein said retarding is provided by a stationary, longitudinally inextensible sheet from member providing a roughened retarding surface engaged with a face of the web.

15. The longitudinal compressive treatment method of claim 14 wherein said retarding surface is provided with cut outs across the width of the web in which the web is not retarded, and maintaining a backing surface above said retarding surface to limit the size of gathered bubbles formed in the regions of said cut outs as adjacent stripes of web are longitudinally compressed, thereby to produce a plisse effect in the web.

16. A process for treating a selected web of material, including as a step, the longitudinal compressive treatment method of claim 1, 2, 3 or 14, and wherein for completion of the process the material requires elevation to a given process-demand level of temperature following the longitudinal compression of the material, said longitudinal compressive treatment step producing a characteristic heat rise in the material of a level that varies relative to the plasticity of the material, said process characterized by the steps of maintaining the material approaching the compressional treatment step at a temperature substantially below said process-demand level temperature and at a state of plasticity adequate to enable the compressive treatment of the material to produce heat rise in the material to said process-demand level temperature, passing the material through said compressive treatment step under conditions to continually produce heat rise in the material to said process-demand level temperature, and employing said temperature in the completion of the process.

17. The compressive treatment process of claim 16 wherein said material is thermoplastic, said process-demand level of temperature is a heat-set temperature of said material, and wherein said longitudinal compressive treatment is conducted to produce heat rise adequate to elevate the temperature of portions of said web to be heat-set.

18. The compressive treatment process of claim 16 wherein said material during said longitudinal compressive treatment contains a volatile softening liquid and said process-demand level temperature is defined as the temperature required to enable evaporation of a major part of said volatile liquid when said web is exposed to ambient conditions.

19. In a process for treating a preformed web of synthetic thermoplastic substance having a heat set temperature of the order of 350°F in which the web in a first passage is driven in longitudinal compressive action against a previously compressed column of the web, the first passage defined by a confining surface and the second passage defined by a retarding surface, said surfaces positioned in succesion over a driven roll, the retarding surface being essentially nonextensible and immobile in the direction of travel of the web to impart an effective retarding action, the improvement for producing a permanently stable, compressively treated web comprising the steps of:

(a) leading untreated web from a supply roll under supply tension to said first passage,

(b) heating said untreated web so that it reaches said first passage in a warmed condition at a temperature below 300°F;

(c) confining said web facewise during its travel through said first and second passages during which it is subjected to compressive treatment;

(d) heating said web as it passes through said first passage to a temperature above 350°F, and

(e) leading the treated web from beneath said retarding surface, under takeup tension through a cooling path by a takeup roll having a surface speed less than the speed of said driven roll whereby a permanently treated smooth-faced and straight web is produced exhibiting no harshness or heat strains.

20. The method of claim 19 wherein said longitudinal compressive action is conducted in the manner to produce a localized heat rise in said synthetic web of more than 50°F, attributable to the conversion to heat of mechanical work energy applied to the substance of the web.

21. The method of claim 19 or 20 comprising employing a driven roll to drive said web for said longitudinal compressive action comprising heating said drive roll to said warmed condition, and disposing the supply roll against said driven roll to maintain surface contact therewith as it unrolls, whereby said web is prewarmed as it reaches the surface of said supply roll, and is further warmed as it moves with the surface of said driven roll to said treatment.

22. A process for treating a selected web or strand of material, including a longitudinal compressive treatment step in which the material is longitudinally compressed, and wherein for completion of the process the material requires elevation to a given process-demand level of temperature following the longitudinal compression of the material, said longitudinal compressive treatment step producing a characteristic heat rise in the material of a level that varies relative to the plasticity of the material, said process characterized by the steps of maintaining the material approaching the compressional treatment step at a temperature substantially below said process-demand level temperature and at a state of plasticity adequate to enable the compressive treatment of the material to produce heat rise in the material to said process-demand level temperature, passing the material through said compressive treatment step under conditions to continually produce heat rise in the material to said process-demand level temperature, and employing said temperature in the completion of the process.

23. The compressive treatment process of claim 22 wherein said material is thermoplastic, said process-demand level of temperature is a heat-set temperature of said material, and wherein said longitudinal compressive treatment is conducted to produce heat rise adequate to elevate the temperature of portions of said web to be heat-set.

24. The compressive treatment process of claim 23 wherein said material comprises synthetic resinous material having a heat set temperature of the order of 350° or higher and including the step of maintaining the temperature of the material approaching said compressional treatment step at a temperature below about 300°F.

25. The compressive treatment process of claim 24 including the step of chilling said web following said longitudinal compressive treatment step to improve the set of said material.

26. The compressive treatment process of claim 25 comprising applying tension to the material to remove at least a portion of the compression of the length of said material prior to said chilling step.

27. The compressive treatment process of claim 23 wherein said material is a preformed web comprised of synthetic thermoplastic fibers, at least some of which extend in the longitudinal direction of said web, said longitudinal compressive treatment step adapted to cause bending and crimping of said longitudinally extending fibers with attendant elevation of the interior fiber temperature and said heat rise effective to heat-set said longitudinally extending fibers in said crimped condition, in situ in said preformed web.

28. The compressive treatment process of any of the claims 23 thru 27 wherein said web comprises a knit or woven textile fabric.

29. The compressive treatment process of claim 22 wherein said compressive treatment is conducted by pressing the material with a stationary surface against a driven gripping surface, thereby to drive the web forward, and opposing the travel of said driven web by a retarding means whereby the web is longitudinally compressed.

30. The process of claim 29 wherein said stationary surface is minutely stepped to provide a series of steps and lands to the material as the material is driven forward and treated.

31. The compressive treatment process of claim 29 wherein said retarding force is applied by a stationary frictional member positioned adjacent the driven gripping surface to define a retarding passage therebetween.

32. The process of claim 31 wherein the downward pressure of said retarding surface is regulated by an air containing-envelope disposed face-to-face over a mediating member lying over said retarding surface, and regulating the air pressure in said envelope to regulate the pressure with which said retarding surface bears against said web.

33. The compressive treatment process of any of the claims 29-32 wherein said substance comprises nylon or polyester including the step of regulating the speed of said longitudinal compressive treatment to the range of 15-50 yards per minute to produce sufficient heat rise to heat-set said material.

34. The compressive treatment process of any of the claims 29-32 wherein said material comprises nylon tricot knit fabric of a thickness between .008 and .012 inch, including maintaining the temperature of the web approaching the compressive treatment step in the range of 240°F to 300°F, and the speed through said longitudinal compressive treatment in the range of 15 to 20 yards per minute, and conducting said longitudinal compressive treatment step in the manner to crimp fibers that extend generally longitudinally in said web, said compressive treatment being sufficient to permanently set the crimp in said fibers.

35. The compressive treatment process of any of the claims 29-32 wherein said material comprises polyester tricot knit fabric of a thickness between .008 and .012 inch, including maintaining the temperature of the web approaching the compressive treatment step in the range of 220°F to 280°F, and the speed through said longitudinal compressive treatment in the range of 15 to 20 yards per minute, and conducting said longitudinal compressive treatment step in the manner to crimp fibers that extend generally longitudinally in said web, said compressive treatment being sufficient to permanently set the crimp in said fibers.

36. The compressive treatment process of claim 22 wherein said material during said longitudinal compressive treatment contains a volatile softening liquid and said process-demand level temperature is defined as the temperature required to enable evaporation of a major part of said volatile liquid when said web is exposed to ambient conditions.

37. The compressive treatment process of claim 36 wherein said material comprises a paper web, said volatile liquid is comprised substantially of water and said process demand level temperature is determined by the drying requirement of said paper.

38. The compressive treatment process of claim 37 adapted to produce a treated kraft paper suitable for use in wrappings and paper bags, said longitudinally compressive treatment step adapted to impart a fine regular effect to the web in which fibers of the web are bent into a finely, barely perceptible microcrepe texture, said process demand level temperature adapted to dry said kraft paper to permanently set said microcrepe texture.

39. The compressive treatment process of any of the claims 36-38 including the step of measuring the concentration of liquid remaining in said web as it leaves said process and based thereupon regulating the application of conditioning liquid to said web prior to said longitudinal compressive treatment step.

40. The compressive treatment process of any of the claims 36-38 wherein said compressive treatment is conducted by pressing the material with a stationary surface against a driven gripping surface, thereby to drive the web forward, and opposing the travel of said driven web by a retarding means whereby the web is longitudinally compressed.

41. The compressive treatment process of claim 40 wherein said retarding force is applied by a stationary frictional member positioned adjacent the driven gripping surface to define a retarding passage therebetween.

42. The process of claim 41 wherein the downward pressure of said retarding surface is regulated by an air containing-envelope disposed face-to-face over the said retarding surface, and regulating the air pressure in said envelope to regulate the pressure with which said retarding surface bears against said web.

43. The process of claim 40 wherein said stationary surface is minutely stepped to provide a series of steps and lands to the material as the material is driven forward and treated.

44. The compressive treatment process of claim 40 wherein said retarding force is applied by a stationary retarding member positioned to divert the web at an angle from said driven gripping surface and an overlying flexible retarding member positioned adjacent said stationary retarding member and defining therewith a retarding passage.

45. In a longitudinal compressive treatment apparatus for treating a web, including a driven roll with a gripping surface for engaging a surface of the web, surface means overlying said roll surface defining in succession a pressing surface and a confining surface, said pressing surface adapted to press the web against the roll surface to drive the web forward in a longitudinal travel direction, said confining surface defining with said roll surface a confining passage in which longitudinal compressive treatment of said web can occur, and retarding means longitudinally downstream of said confining passage for retarding the movement of said web in said travel direction to cause compressed material to accumulate, whereby untreated material in said confining passage can longitudinally compress against previously compressed material, the improvement wherein said confining surface comprises a series of minor, discrete steps, said steps being arranged so that the height of said confining surface above said roll surface is discretely enlarged in minor amounts relative to the thickness of the web progresively along said travel direction, to define a series of adjacent, dimensionally similar compressive treatment zones whereby, in the presence of change in conditions that tend to shift the place where compressive treatment occurs, the major point of treatment can occur alternatively in different of said series of adjacent treatment zones.

46. The longitudinal compressive treatment apparatus of claim 45 wherein said confinement surface having said steps is defined by an integral extension of a member defining said pressing surface.

47. In a longitudinal compressive treatment apparatus for treating a web, including a web supply means adapted to apply tension to an untreated web being drawn from said supply, a driven roll with a gripping surface for engaging a surface of the web, surface means overlying said roll surface defining, in succession, a pressing surface and a confining surface, said pressing surface adapted to press the web against the roll surface to draw the web from said supply means and drive the web forward in a longitudinal travel direction, said confining surface defining with said roll surface a confining passage in which longitudinal compressive treatment of said web can occur, and retarding means longitudinally downstream of said confining passage for retarding the movement of said web in said travel direction to cause compressed material to accumulate, whereby untreated material in said confining passage can longitudinally compress against previously compressed material, the improvement wherein said surface means defines at least two discrete successive steps, the edge of the first of said steps defining a concentrated drive pressure point by which the web is tightly pressed against the drive roll surface to apply drive force on the web to draw the web from said web supply means, said first step being of minor dimension whereby the portion of said surface means that extends downstream from said first step confines the web to continued movement on the roll in a relatively tensionless state, essentially without compaction and slippage of the web relative to said roll until the web reaches said second step being arranged so that the height above said roll surface of the portion of said surface means that extends downstream from said second step is discretely enlarged to define a treatment zone in which longitudinal compressive treatment occurs with slippage of the web relative to said drive roll, the edge of said second

step adapted to define a second concentrated drive pressure point by which the web is tightly pressed against the drive roll surface to apply drive force to drive the web forward into said longitudinal compressive treatment zone.

48. The longitudinal compressive treatment apparatus of claim 47 wherein beyond said first step said confining surface comprises a plurality of additional, discrete steps, said steps being arranged so that the height of said confining surface above said roll surface is discretely enlarged in minor amounts relative to the thickness of the web progressively along said travel direction, to define a series of adjacent, dimensionally similar compressive treatment zones whereby, in the presence of change in conditions that tend to shift the place where compressive treatment occurs, the major point of treatment can occur alternatively in different of said series of adjacent treatment zones.

49. The longitudinal compressive treatment apparatus of claim 45, 46, 47, or 48 wherein said surface means is defined by a stationary member defining a series of essentially planar and smooth lands joined by successive discrete, minor riser portions extending at substantial angles to said planar lands.

50. The longitudinal compressive treatment apparatus of claim 45, 46, 47 or 48 wherein said surface means is defined by a sheet form metal member having said steps formed integrally in the surface thereof.

51. The longitudinal compressive treatment apparatus of claim 50 wherein said metal member is a sheet of steel in which said steps are of ground form.

52. The longitudinal compressive treatment apparatus of claim 45, 46, 47 or 48 wherein said steps are of the order of 0.003 inches height.

53. The longitudinal compressive treatment apparatus of claim 52 wherein the portions of said surface means extending between adjacent steps are of the order of 0.050 inches in longitudinal extent.

54. The longitudinal compressive treatment aparatus of claim 45, 46, 47 or 48 adapted for treatment of a predetermined web material, wherein the height of each step is no more than about one third of the thickness of the material.

55. The longitudinal compressive treatment apparatus of claim 45, 46, or 47 wherein said surface means defines at least three steps that bound longitudinal compressive treatment zones.

56. The longitudinal compressive treatment apparatus of claim 45, 46, 47 or 48 wherein said retarding means defines a surface following said confining surface, the member defining the end of said confining surface having a minor thickness relative to the thickness of the web, whereby the end portion of said member enables transfer of the material from under the confining surface to under the retarding surface without substantial change in passage dimension.

57. The longitudinal compressive treatment apparatus of claim 56 wherein the thickness of the end of said member is of the order of 0.003 inch.

58. The longitudinal compressive treatment apparatus of claim 56 wherein said retarding means comprises a stationary sheet form member overlying said roll surface and defining therewith a retarding passage, the member defining the end of said confining surface adapted to direct the web into said retarding passage in a direction substantially parallel to the surface of said retarding member.

59. The longitudinal compressive treatment apparatus of claim 58 wherein said stationary sheet form member comprises a sheet having a roughened surface.

60. The longitudinal compressive treatment apparatus of claim 56 in which there is a sheet form member of spring steel which has a portion lying over said surface means and a portion which extends therebeyond along said retarding surface, said sheet from member positioned to transmit downward pressure to web under said confining surface and said retarding surface, a cut out notch provided in the upper surface of said sheet form member providing an integral flexible hinge, said notch positioned on the upper surface of said sheet from member, in the region between said confining and said retarding surfaces, and serving to decouple said portions of said sheet metal member to provide relative force isolation of said two portions while providing a continuous and flexible transition therebetween.

61. The apparatus of claim 60 wherein a fluid-expansible envelope extends over the portion of said sheet form member at said retarding surface and means to control the fluid pressure within said envelope to controllably vary the pressure with which said portion presses said retarding surface against said web.

62. In a longitudinal compressive treatment apparatus for treating a web, including a driven roll with a gripping surface for engaging a surface of the web, surface means overlying said roll surface defining therewith a pressing and confining passage for pressing the web against the roll surface to drive the web forward in a longitudinal travel direction, and longitudinally downstream thereof means defining a retarding passage for retarding the movement of said web in said travel direction to cause compressed material to accumulate, whereby untreated material can longitudinally compress against previously compressed material, there being a sheet form member of spring steel which has a portion lying over said surface means and a downstream portion which extends therebeyond along said retarding passage, said sheet form member positioned to transmit downward pressure to web in said pressing and confining passage and said retarding passage, the improvement wherein a cut out notch is provided in the upper surface of said sheet form member providing an integral flexible hinge, said notch positioned on the upper surface of said sheet form member, in the region between said pressing and confining passage and said retarding passage, and serving to decouple said portions of said sheet metal member to provide relative force isolation of said two portions while providing a continuous and flexible transition therebetween.

63. The apparatus of claim 62 wherein said retarding passage is defined on one side by the surface of said roll and on the other side by a stationary retarding surface, the downstream portion of said spring steel sheet member arranged to press said stationary retarding surface against the face of the web while accommodating blooming expansion of the web without disruption of the geometry of the pressing and confining passage.

64. The apparatus of claim 53 wherein said retarding passage is defined on one side by a stationary retarder held adjacent to said driven roll in a position to divert the web away therefrom, and on the other side by an opposed surface, the downstream portion of said spring steel sheet member being bent at said notch to follow the direction of said stationary retarder to position said opposed surface relative to said stationary retarder.

65. In a longitudinal compressive treatment apparatus for treating a web, including a driven roll with a gripping surface for engaging a surface of the web, surface means overlying said roll surface defining therewith a pressing and confining passage for pressing the web against the roll surface to drive the web forward in a longitudinal travel direction, and longitudinally downstream thereof means defining a retarding passage for retarding the movement of said web in said travel direction to cause compressed material to accumulate, whereby untreated material can longitudinally compress against previously compressed material, there being a sheet from member of spring steel which has a portion lying over said surface means and a downstream portion which extends therebeyond along said retarding passage, said sheet from member positioned to transmit downward pressure to web in said pressing and confining passage and said retarding passge, the improvement wherein a fluid-expansible envelope extends over the downstream portion of said sheet form member along said retarding passage and means to control the fluid pressure within said envelope to controllably vary the retarding pressure exerted in the retarding passage against said web.

66. The apparatus of claim 65 wherein a substantially rigid reaction member is disposed above said envelope, said envelope effective to press and react against said reaction member whereby the effect of said envelope is directed substantially downward against said sheet form member.

67. The machine of claim 65 or 66 wherein said downstream postion of said sheet form member carries an abrasive surface engaging the face of the web, said sheet from member serving to spread pressure of said envelope substantially uniformly over said abrasive surface.

68. The machine of claim 65 or 66 wherein to ensure a downward pressure mediating effect over a wide range of operating pressures said sheet from member of spring metal has a thickness of at least .010".

69. A universal cavity-defining member for use in the drive and treatment region of a microcreper, said member adapted to be held over a drive roll and pressed thereagainst by pressing means, said member characterized by a plurality of successive spaced apart steps having a depth of the order of .003 inches each.

70. A textile fabric formed from a uniform sheet comprised of mechanically compressed smooth stripe regions in which the fabric is tightly compacted in its own plane and less flat, and intervening bubble regions lying between adjacent stripe regions, the fabric in said regions being substantially uncompacted and being in the from of successive bubbles.

71. The textile fabric of claim 70 suitable for child's clothes, comprised of tubular knit heat settable material, said stripes of compaction being permanent as a result of heat setting.

72. The textile fabric of claim 71 in which said fabric is 100 percent polyester and has a compacted weight of the order of 4.5 square yards per pound, and averages about 25 courses per inch after compacting.

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FIG 1

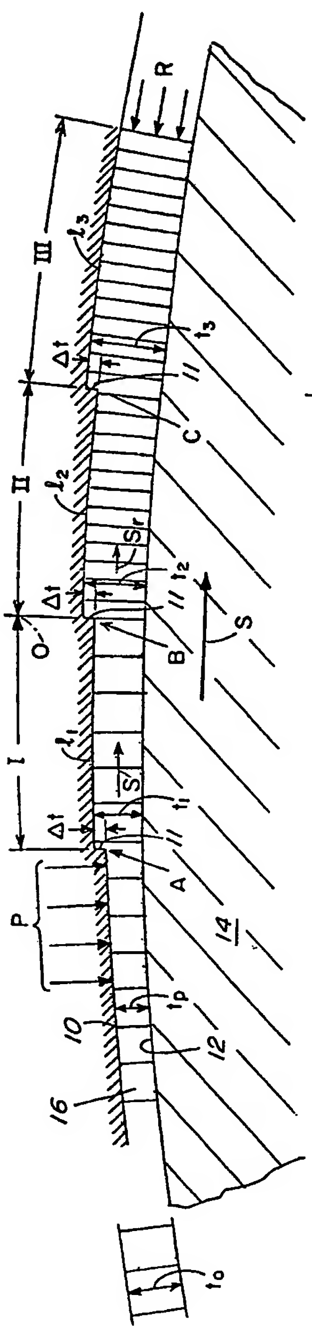


FIG 2

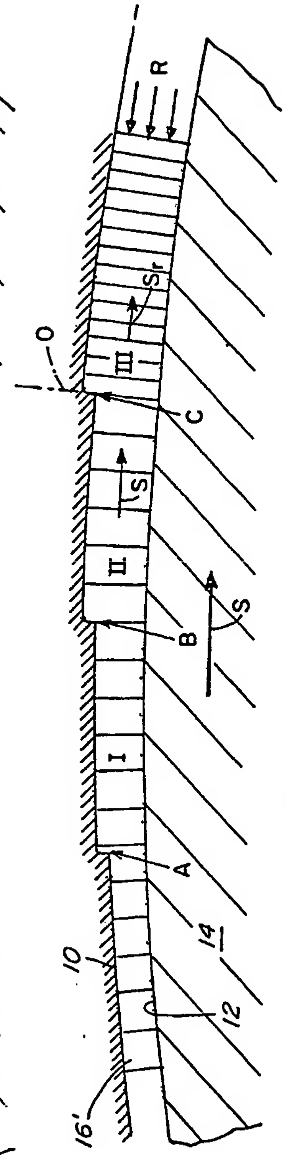
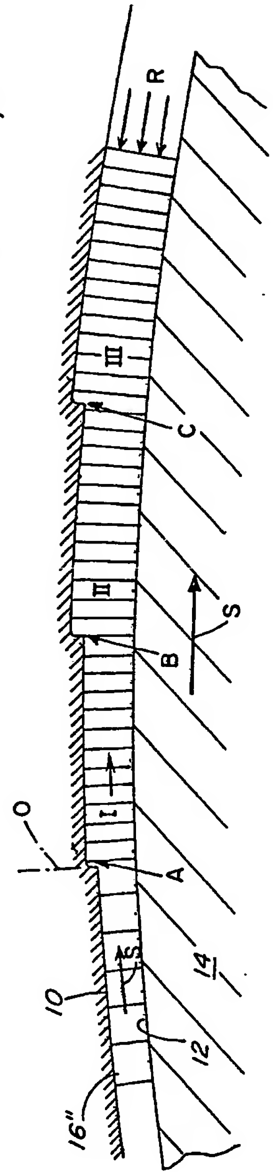


FIG 3



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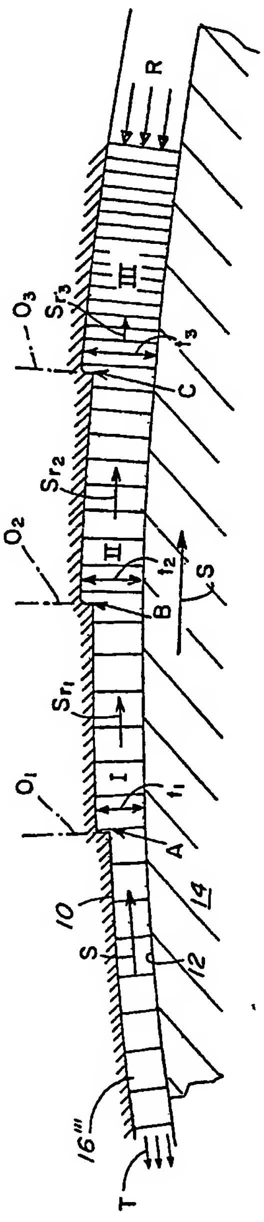


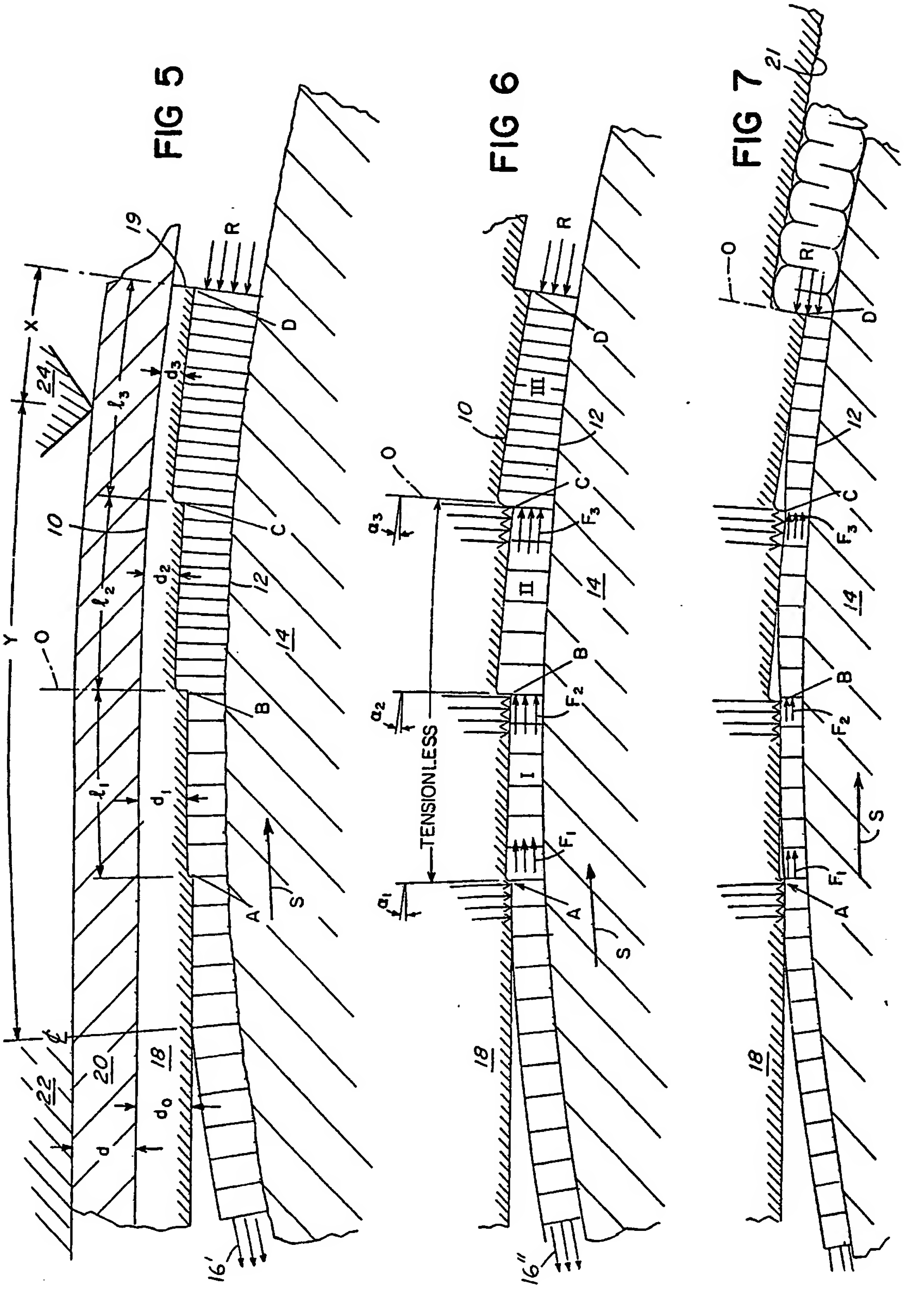
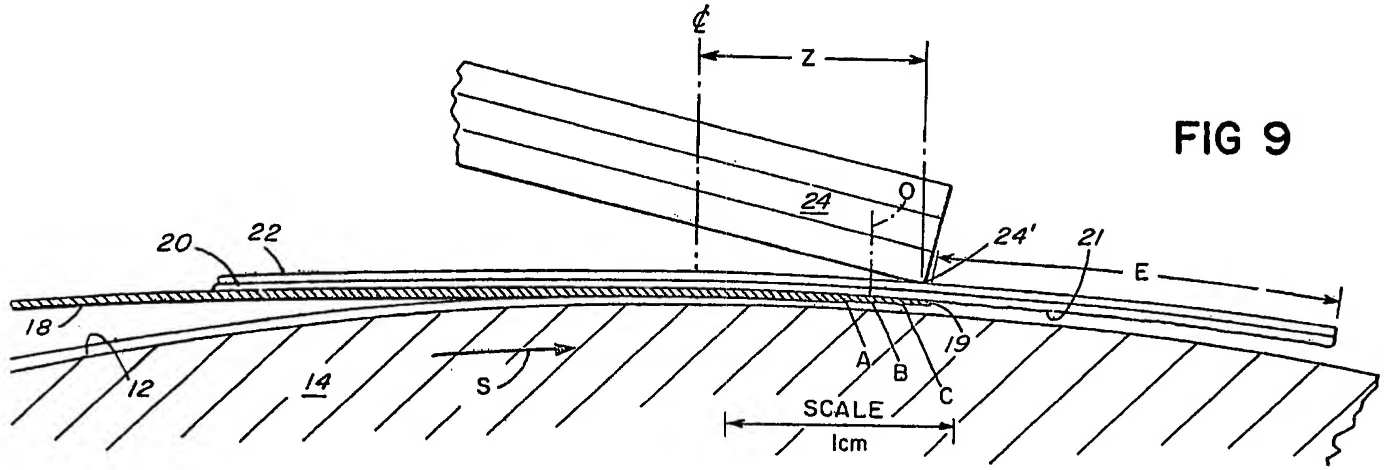
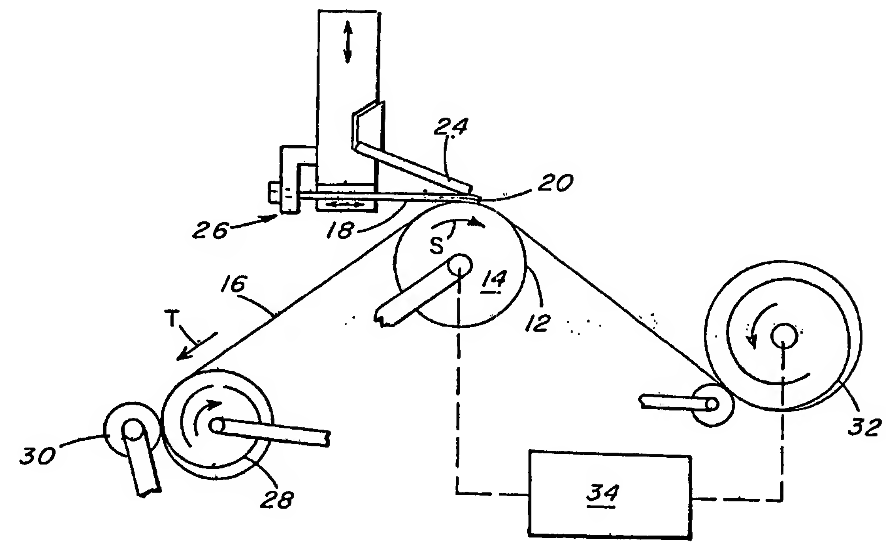


FIG 5
FIG 6
FIG 7
TENSIONLESS
X
Y
R
S
A
B
C
D
O
I
II
III
10
12
14
18
19
20
21
22
24
16'
16"



Z
24
O
24'
21
E
20
22
18
12
14
S
A
B
C
19
SCALE
Icm

FIG 9



24
20
26
18
S
14
12
16
T
30
28
32
34

FIG 8

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FIG 9a

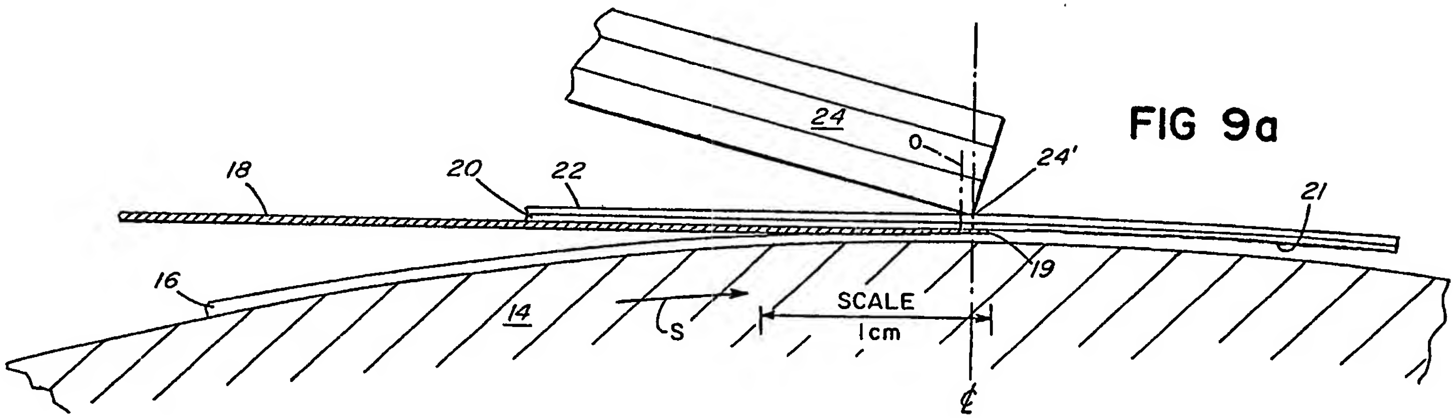


FIG 9b

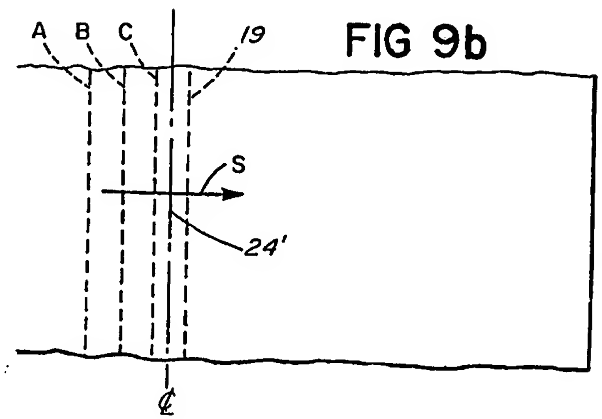


FIG 9c

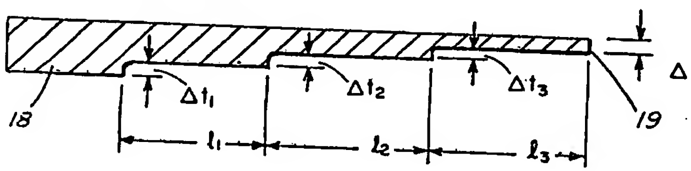


FIG 9d

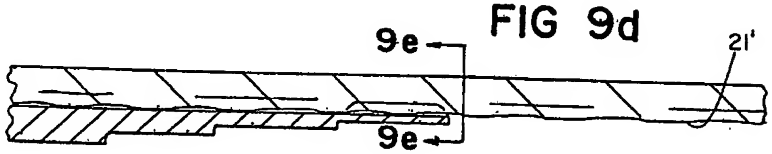
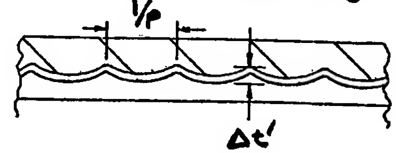


FIG 9e



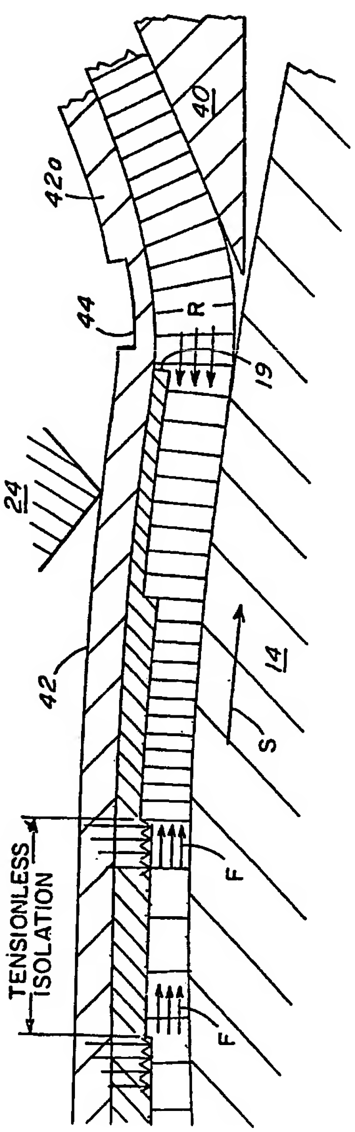


FIG 10

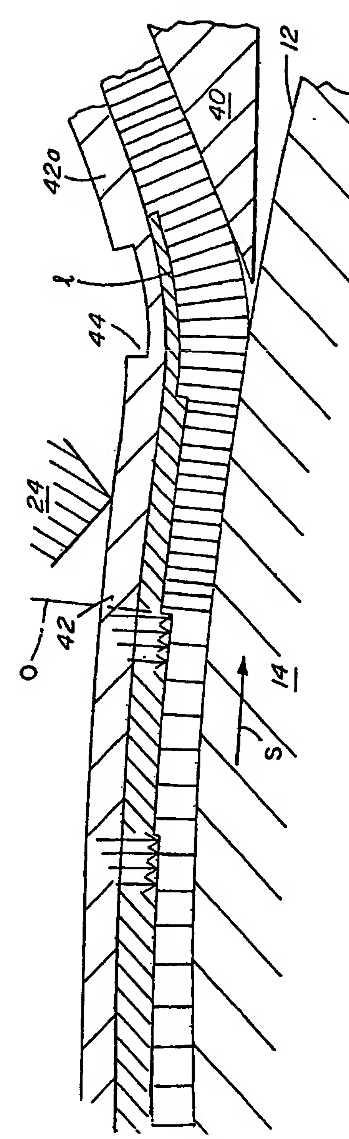


FIG 10a

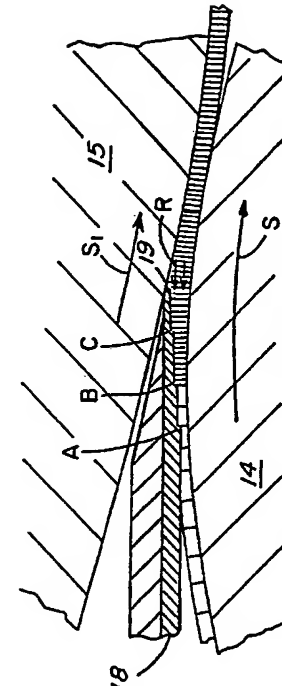


FIG 12

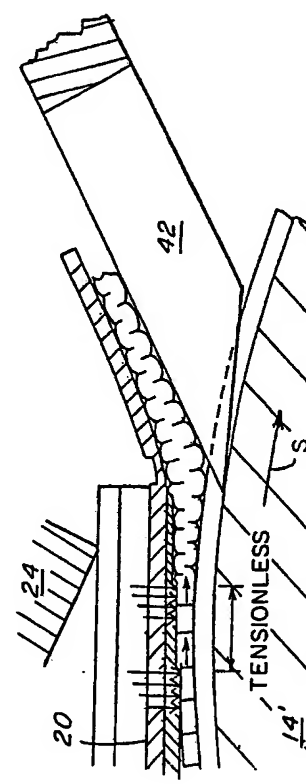


FIG 11

FIG 13

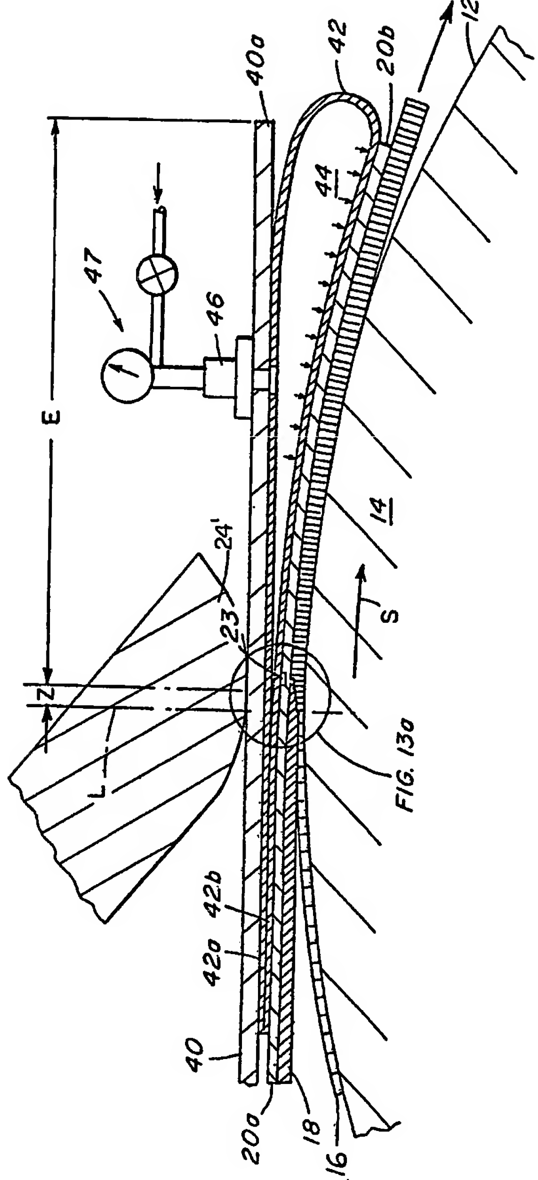


FIG 13a

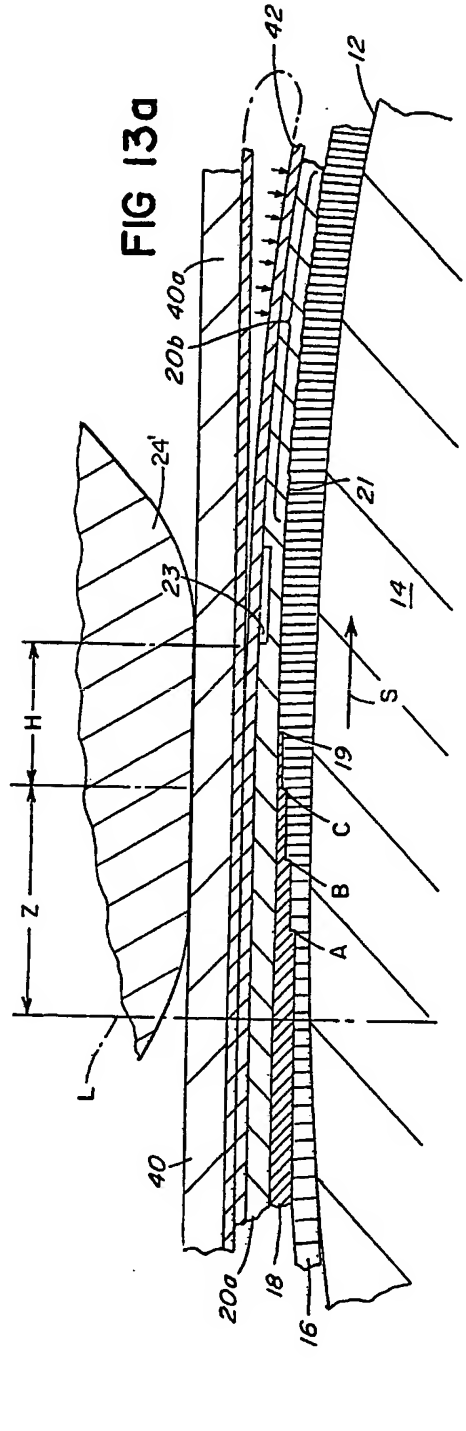


FIG 14

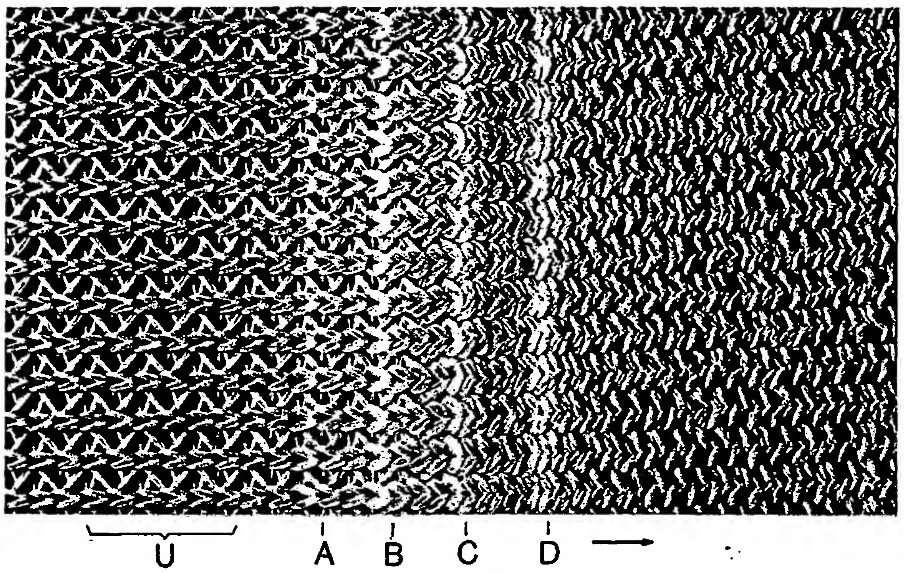


FIG 15

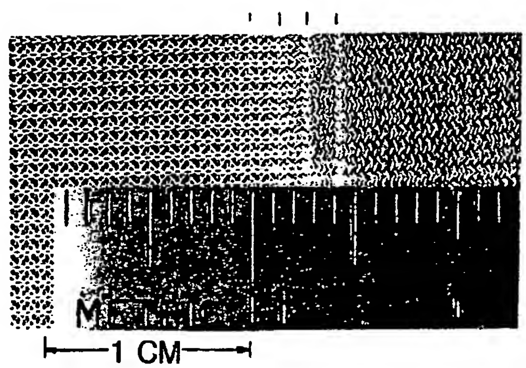


FIG 16

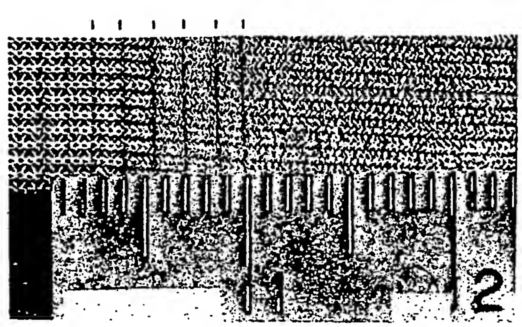
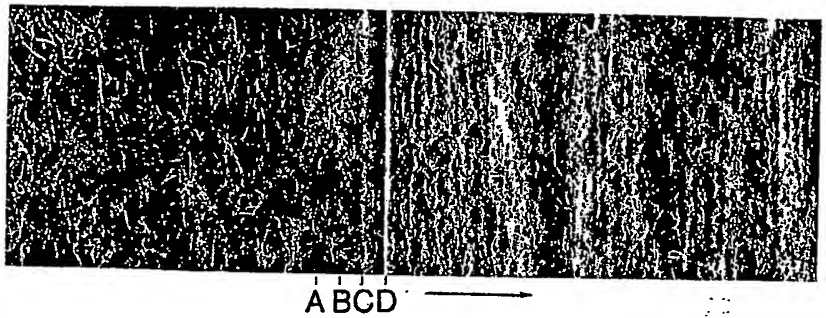


FIG 17



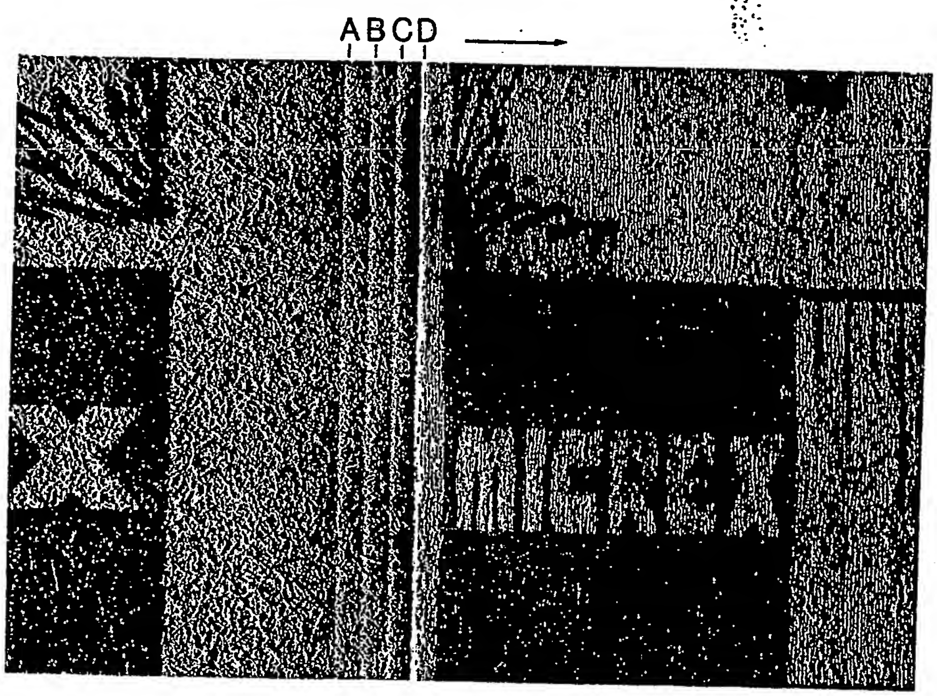


FIG 18

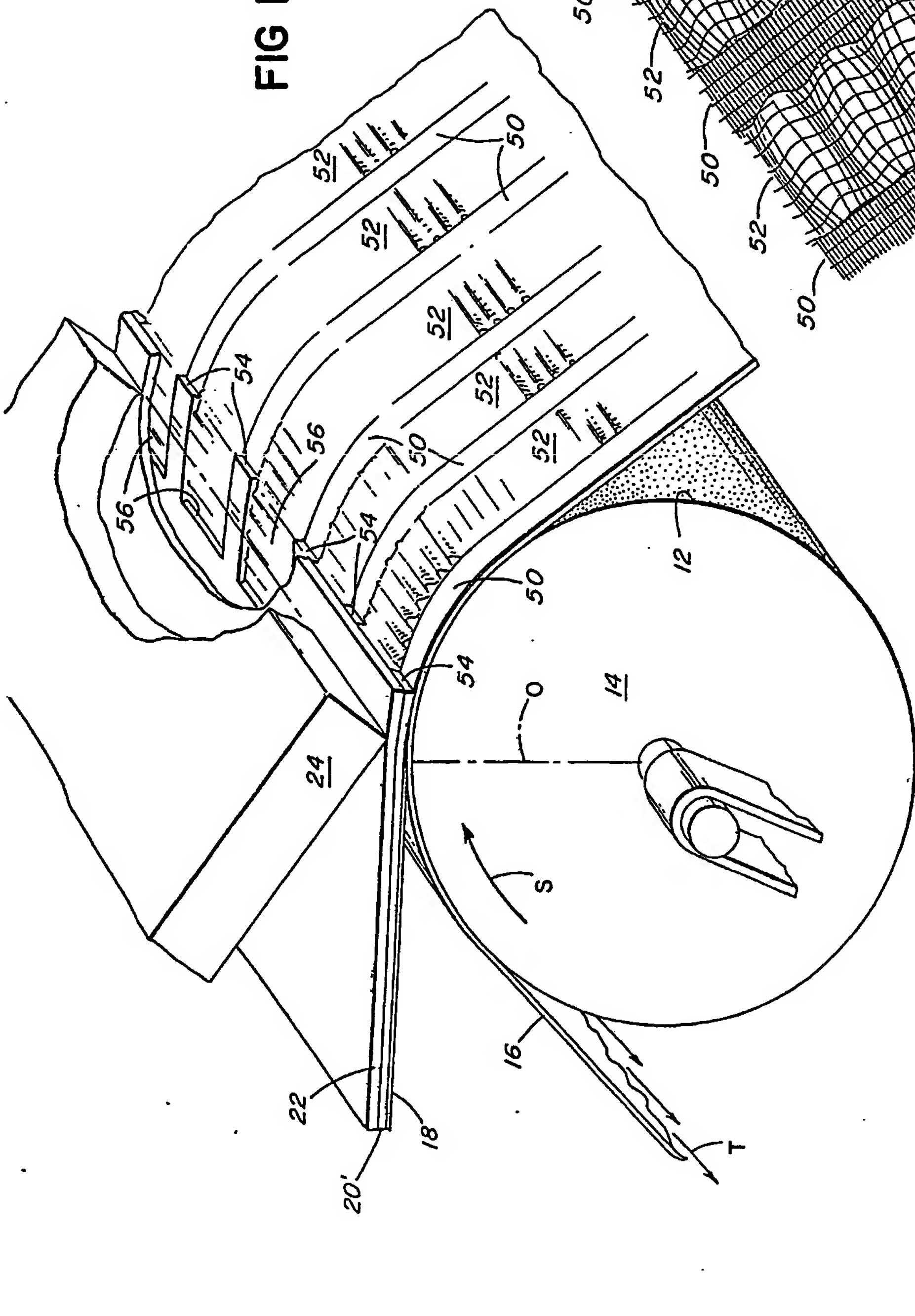


FIG 19

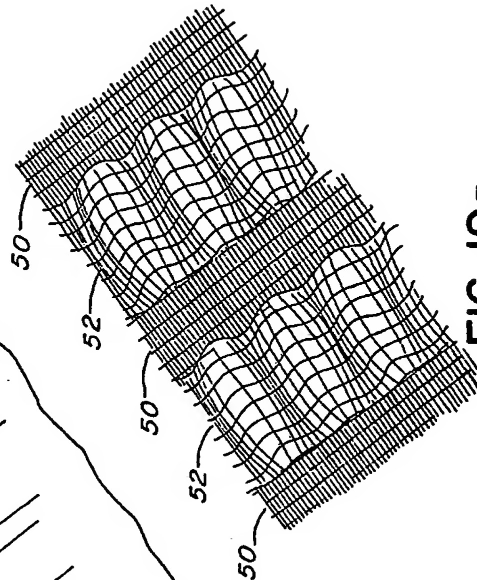


FIG 19a

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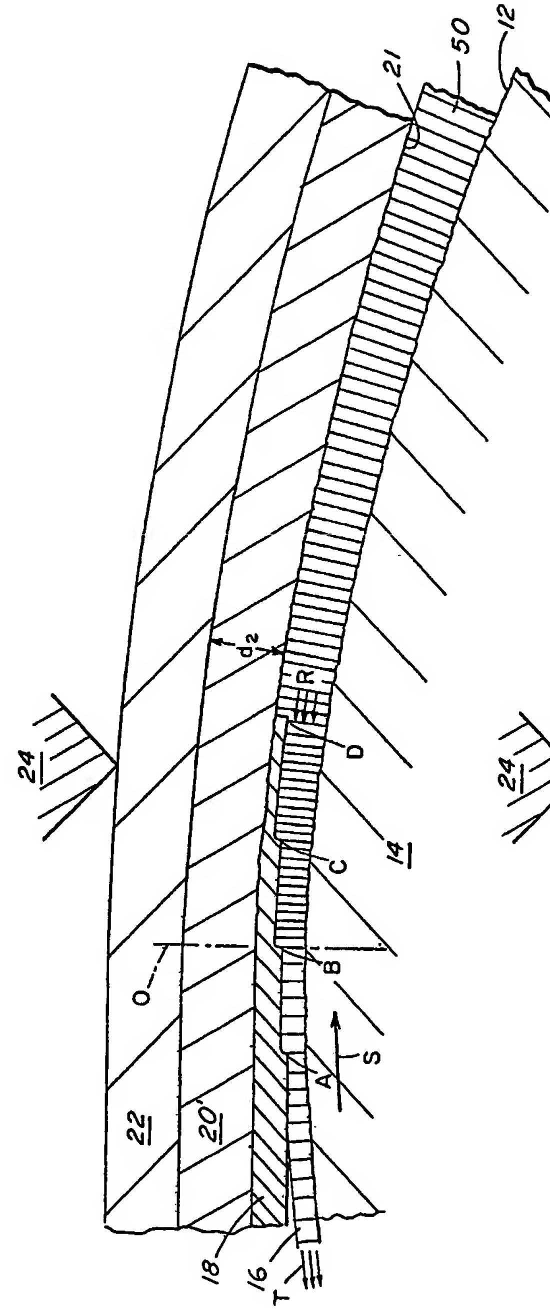

FIG 20

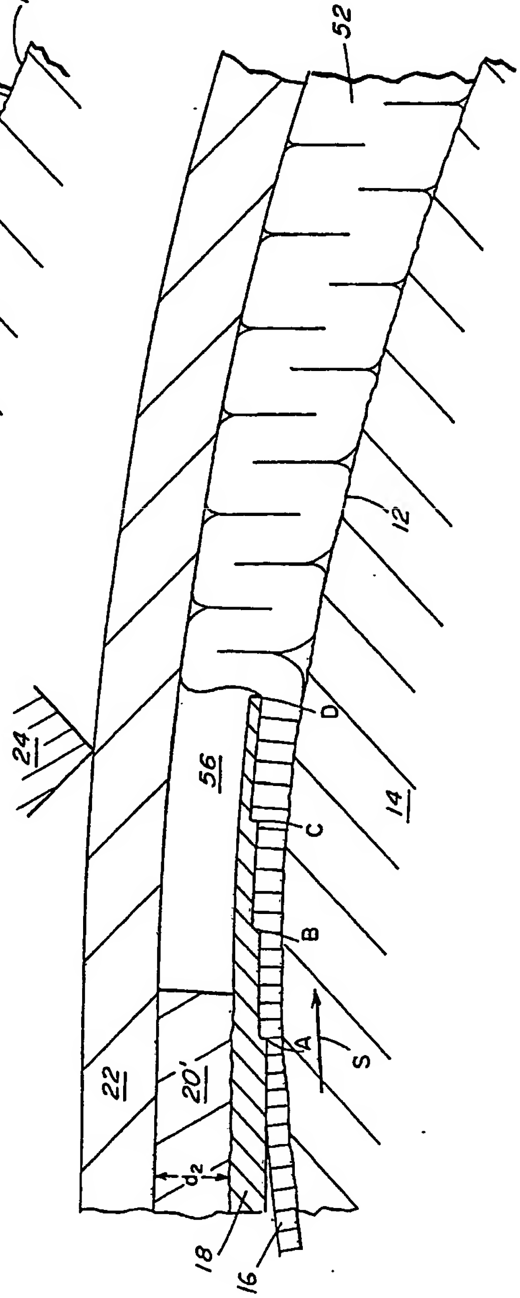

FIG 20a

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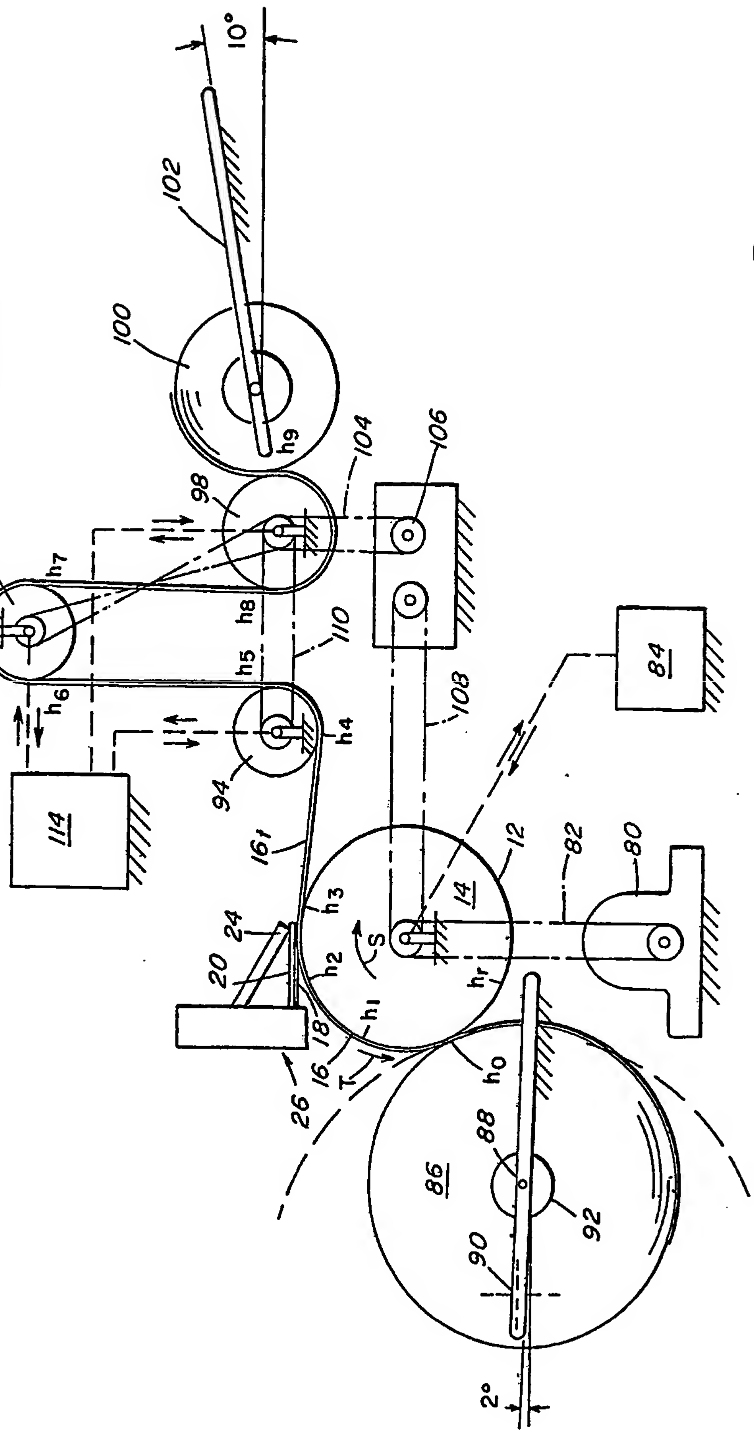

FIG 21

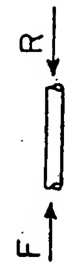

FIG 22

FIG 23

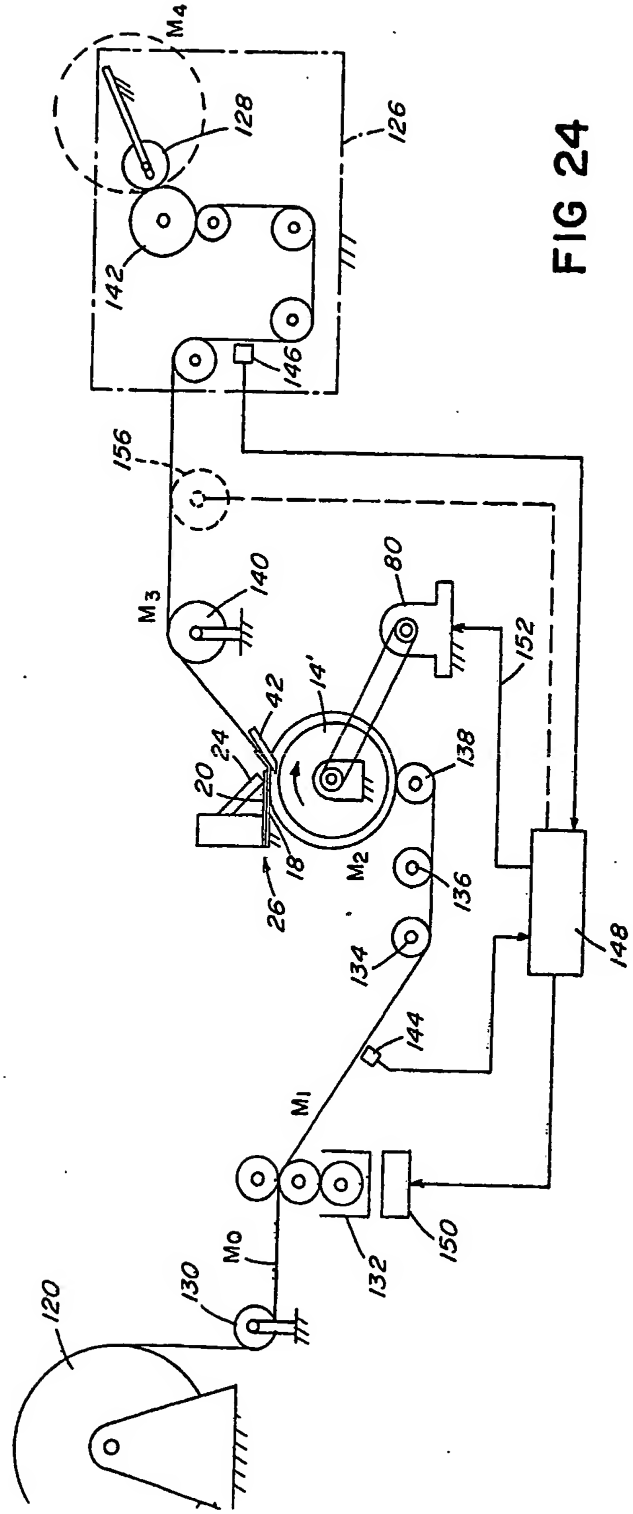
M4
128
126
142
146
156
M3
140
80
152
42
14'
24
20
138
M2
18
26
136
148
134
144
M1
150
132
Mo
130
120

FIG 24

European Patent Office

EUROPEAN SEARCH REPORT

0047397

Application number
EP 81 10 6096

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.³)
	US - A - 3 390 218 (JOHNSON & JOHNSON) * Whole document * --	1-4	D 06 C 21/00
	US - A - 3 556 921 (JOHNSON & JOHNSON) * Whole document * --	1-4	
D	US - A - 3 869 768 (WALTON) * Whole document * --	1	TECHNICAL FIELDS SEARCHED (Int. Cl.³)
D	US - A - 3 975 806 (WALTON) * Whole document * --	1	D 06 C 21/00
A	US - A - 3 641 234 (BANCROFT)		
A	FR - A - 2 361 222 (TILBURG) -----		

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	13-11-1981	PETIT

EPO Form 1503.1 06.78